华章科技

VIKING

畅销书《The Age of Spiritual Machines》作者又一力作

《纽约时报》评选的“2005年度博客谈论最多的图书”之一

奇点临近

The Singularity Is Near

When Humans Transcend Biology

2045年，当计算机智能超越人类

（美）Ray Kurzweil 著

李庆诚 董振华 田源 译



2005年CBS News评选的畅销书

2005年美国最畅销非小说类图书

2005年亚马逊最佳科学图书

比尔·盖茨、比尔·乔伊等鼎力推荐

一部预测人工智能和科技未来的奇书

机械工业出版社
China Machine Press

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The Singularity Is Near:When Humans Transcend Biology

[[illegible]]Ray Kurzweil [illegible]

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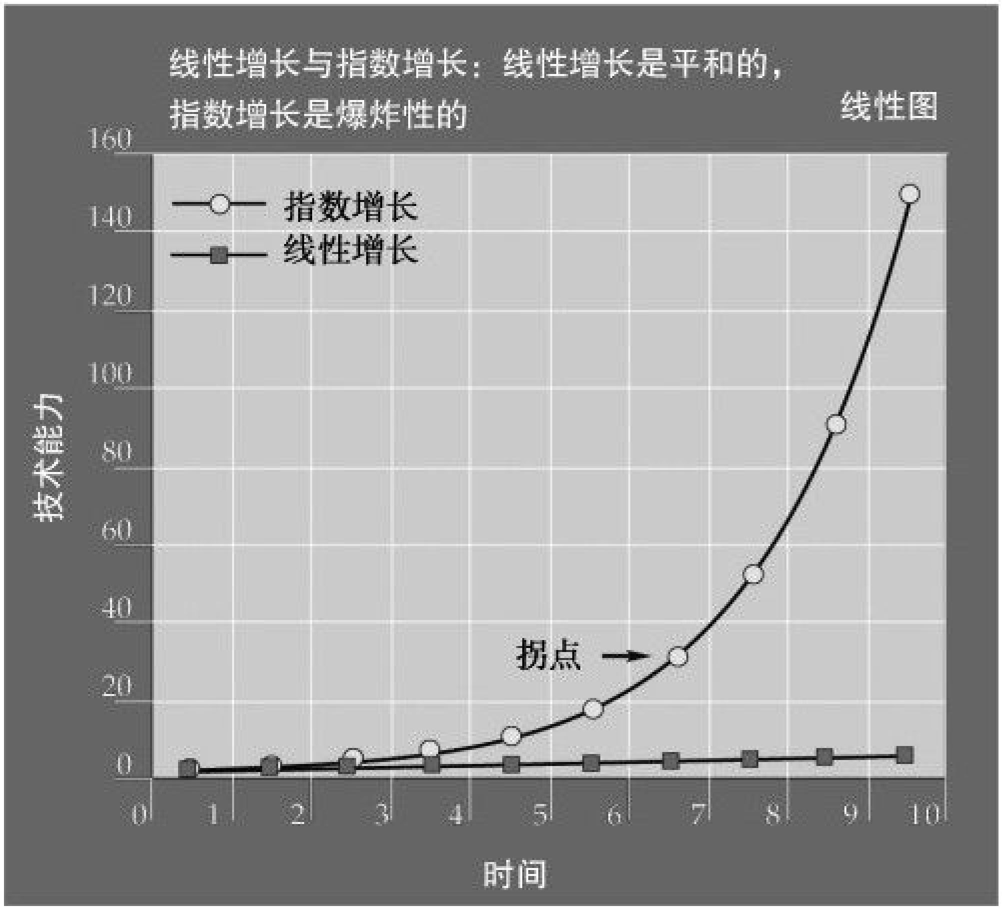
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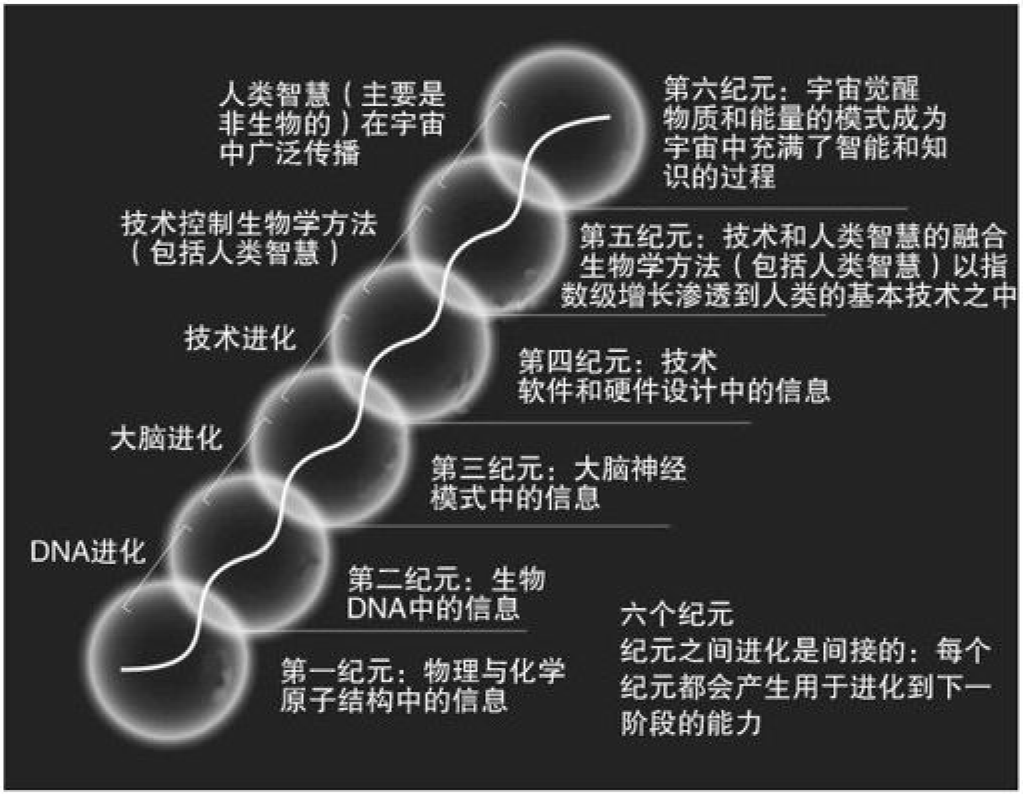
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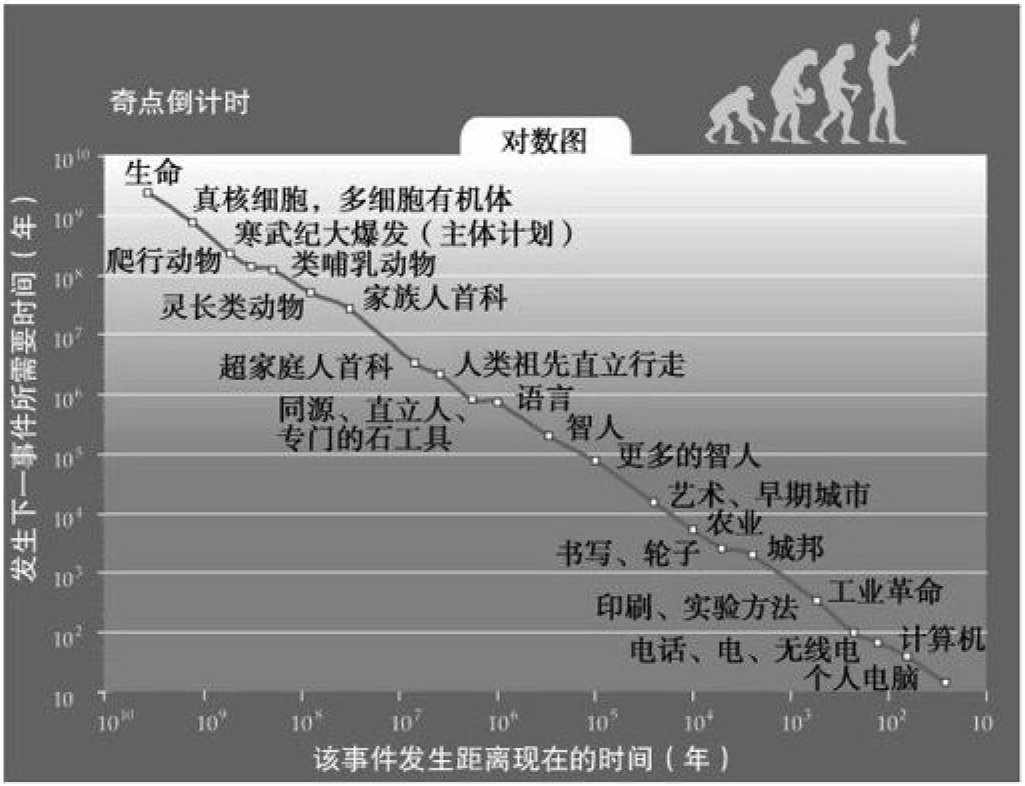
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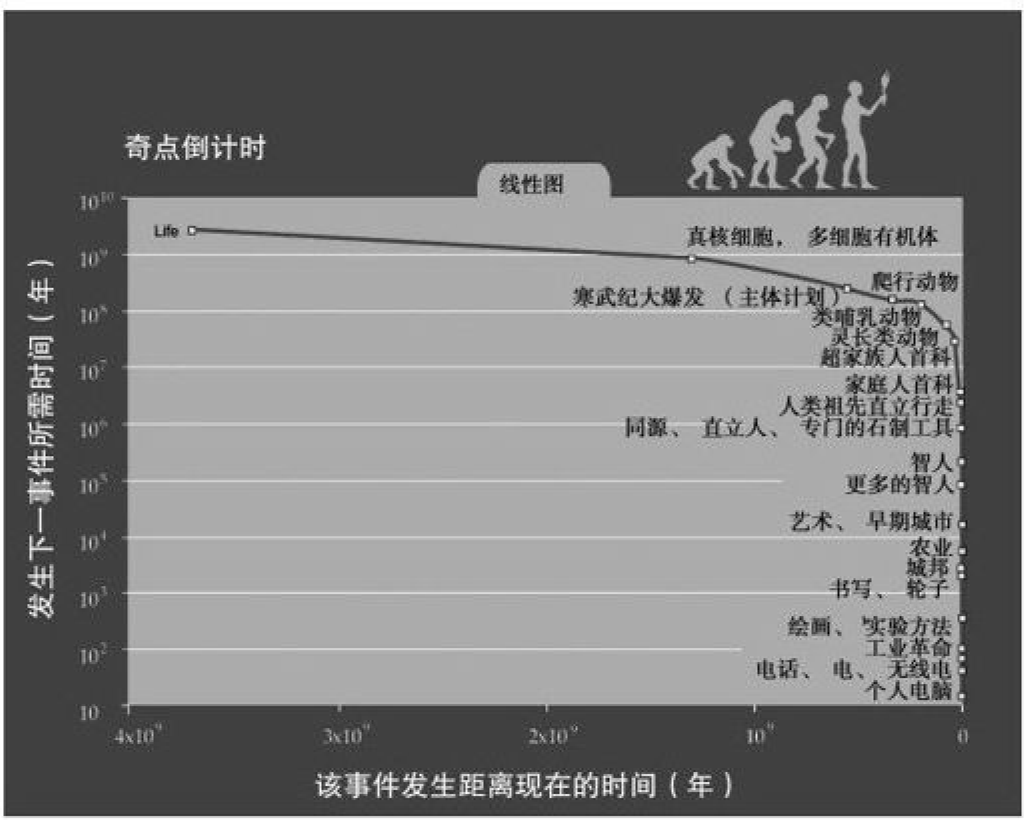
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城邦
工业革命
印刷、实验方法
计算机
电话、电、无线电
个人电脑
发生下一事件所需要时间（年）
该事件发生距离现在的时间（年）

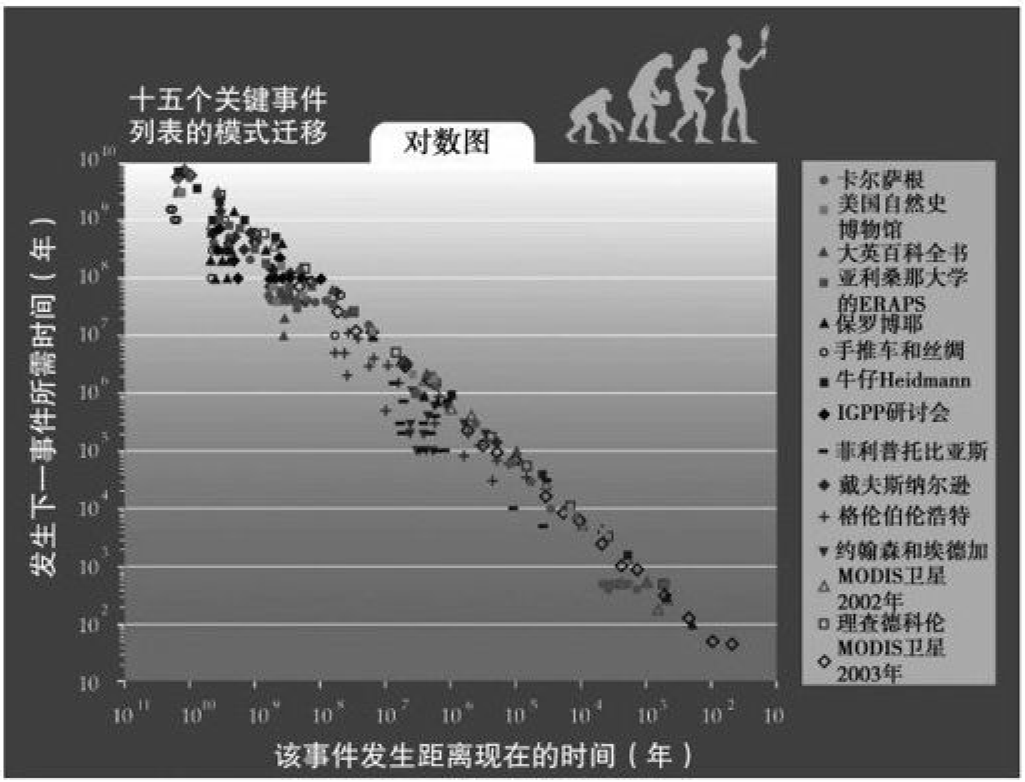
图 1-3



奇点倒计时
线性图
Life
真核细胞，多细胞有机体
爬行动物
寒武纪大爆发（主体计划）
类哺乳动物
灵长类动物
超家族人首科
家庭人首科
人类祖先直立行走
同源、直立人、专门的石制工具
智人
更多的智人
艺术、早期城市
农业
城邦
书写、轮子
绘画、实验方法
工业革命
电话、电、无线电
个人电脑
发生下一事件所需时间（年）
该事件发生距离现在的时间（年）

□ 1-4

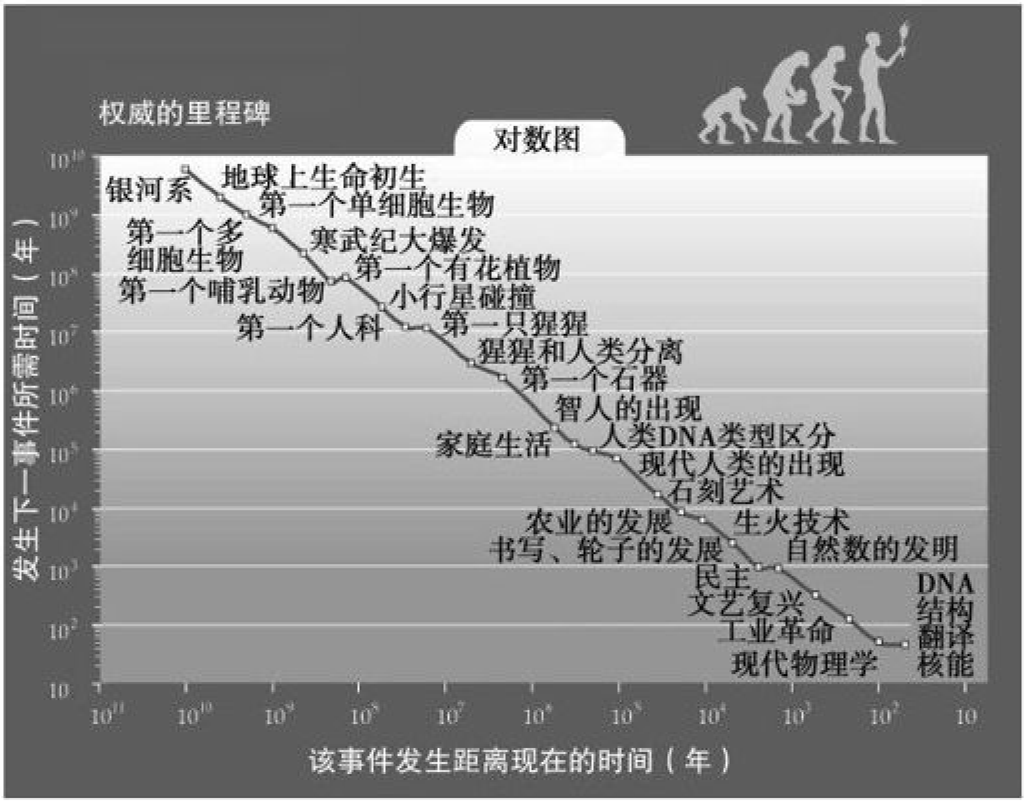
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□ 1-5

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权威的里程碑
对数图
银河系
地球上生命初生
第一个单细胞生物
第一个多细胞生物
寒武纪大爆发
第一个有花植物
第一个哺乳动物
小行星碰撞
第一个人科
第一只猩猩
猩猩和人类分离
第一个石器
智人的出现
家庭生活
人类DNA类型区分
现代人类的出现
石刻艺术
农业的发展
生火技术
书写、轮子的发展
自然数的发明
民主
文艺复兴
工业革命
现代物理学
DNA结构
翻译
核能
发生下一事件所需时间（年）
该事件发生距离现在的时间（年）

1-6

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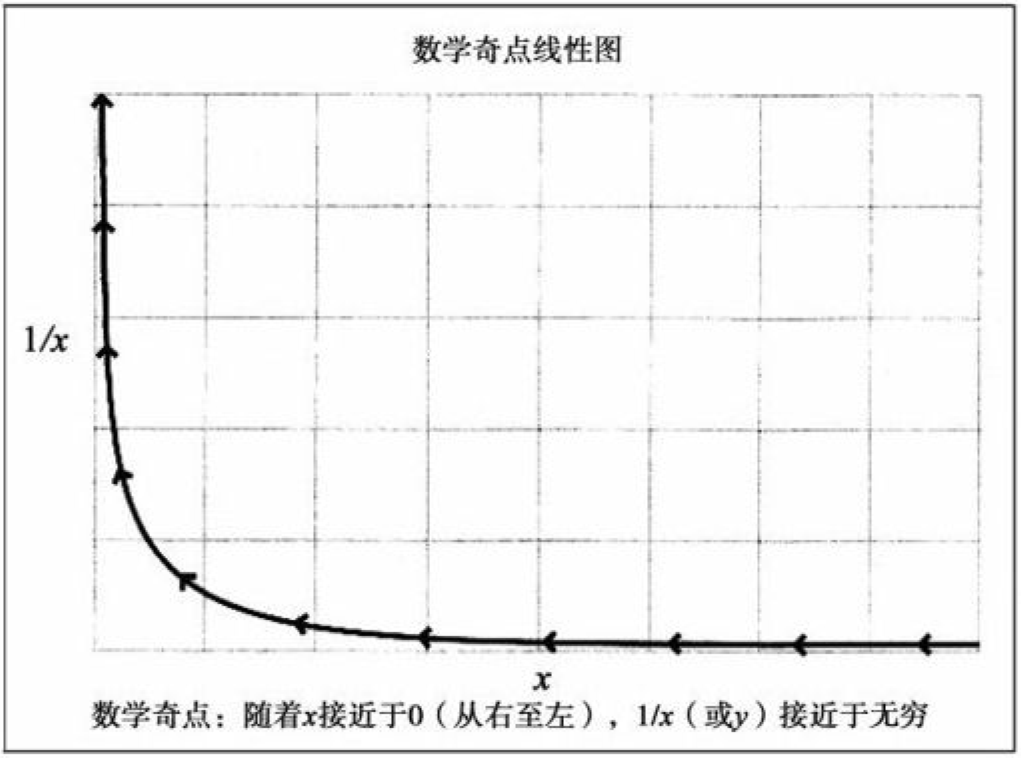
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□ 1-7

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Mind Children[21]1993

NASA“”

[22]1999The Age of Spiritual Machines

Whencomputers Exceed Human Intelligence

[23]1999·Robot

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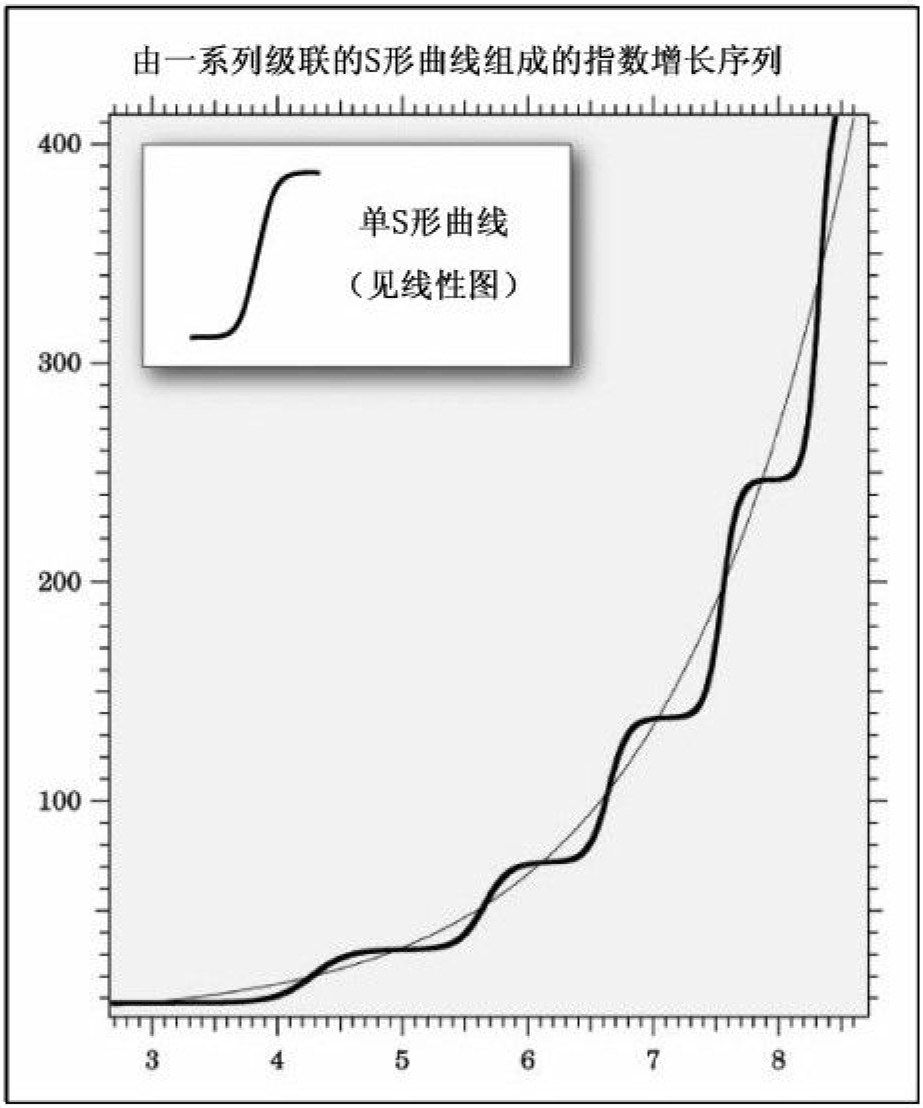
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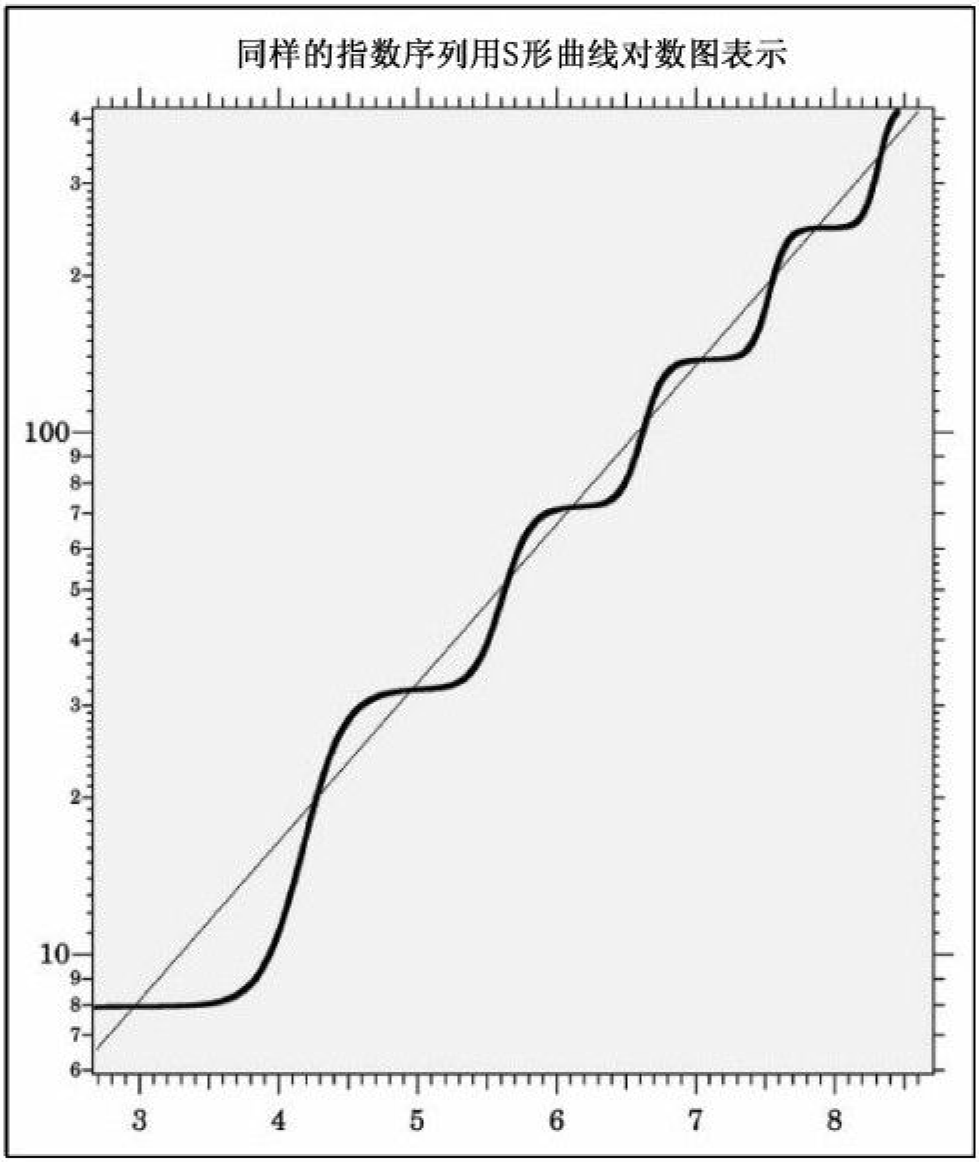
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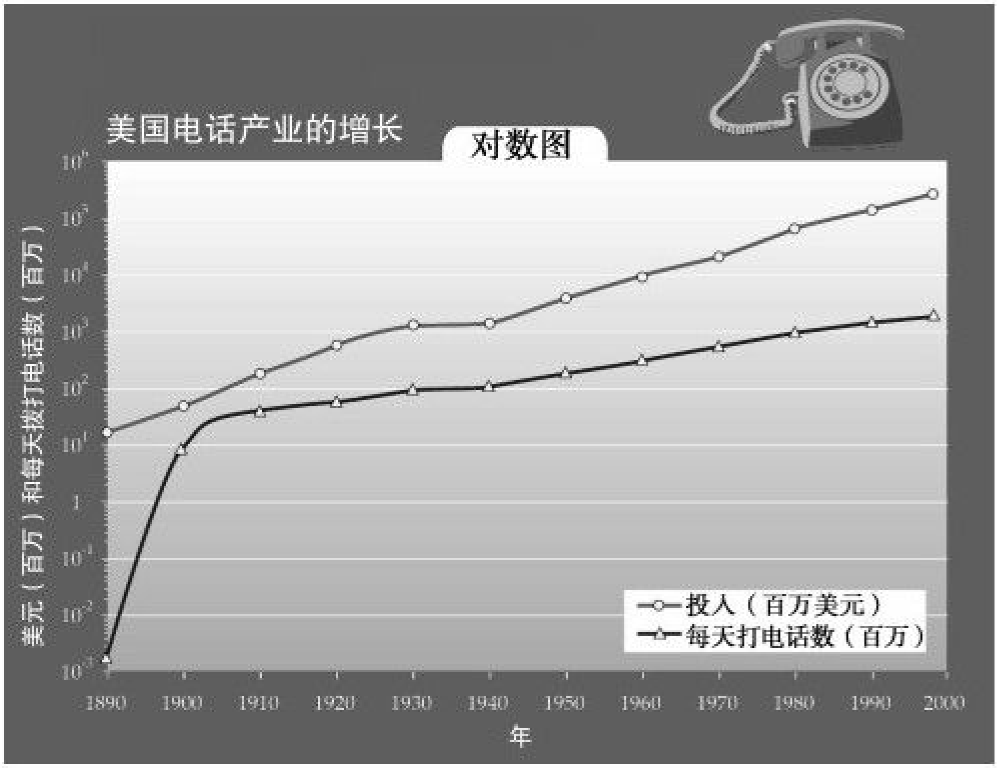

美国电话产业的增长
对数图
美元（百万）和每天拨打电话数（百万）
投入（百万美元）
每天打电话数（百万）
年

图 2-3

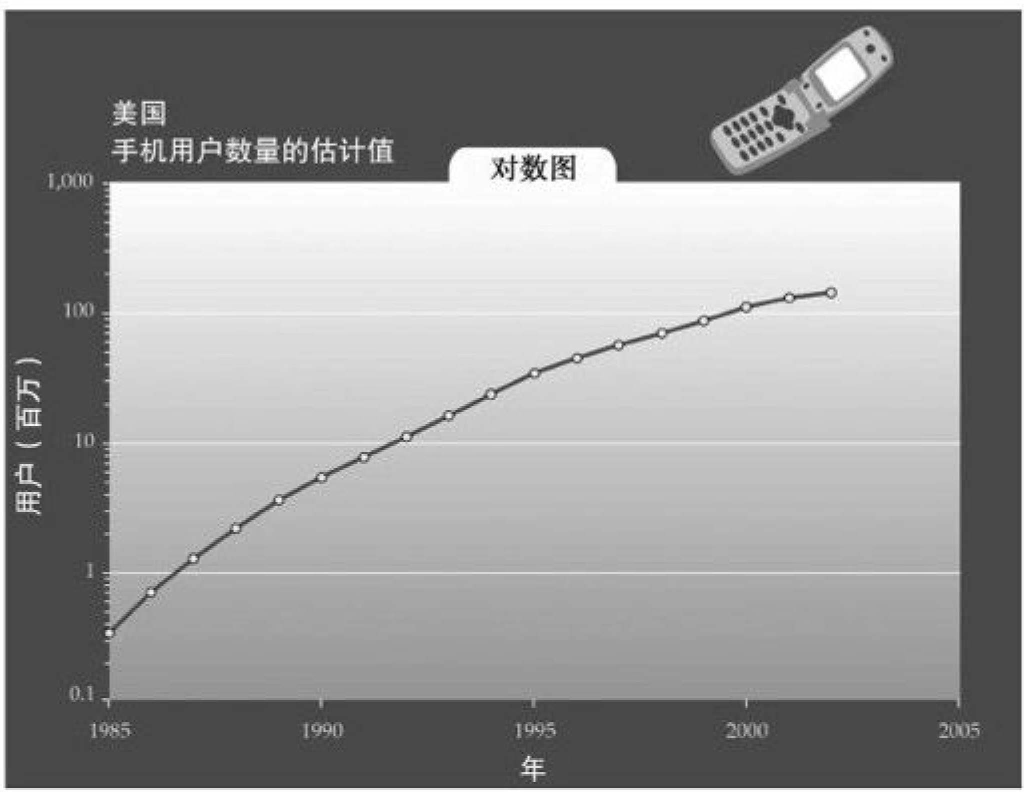
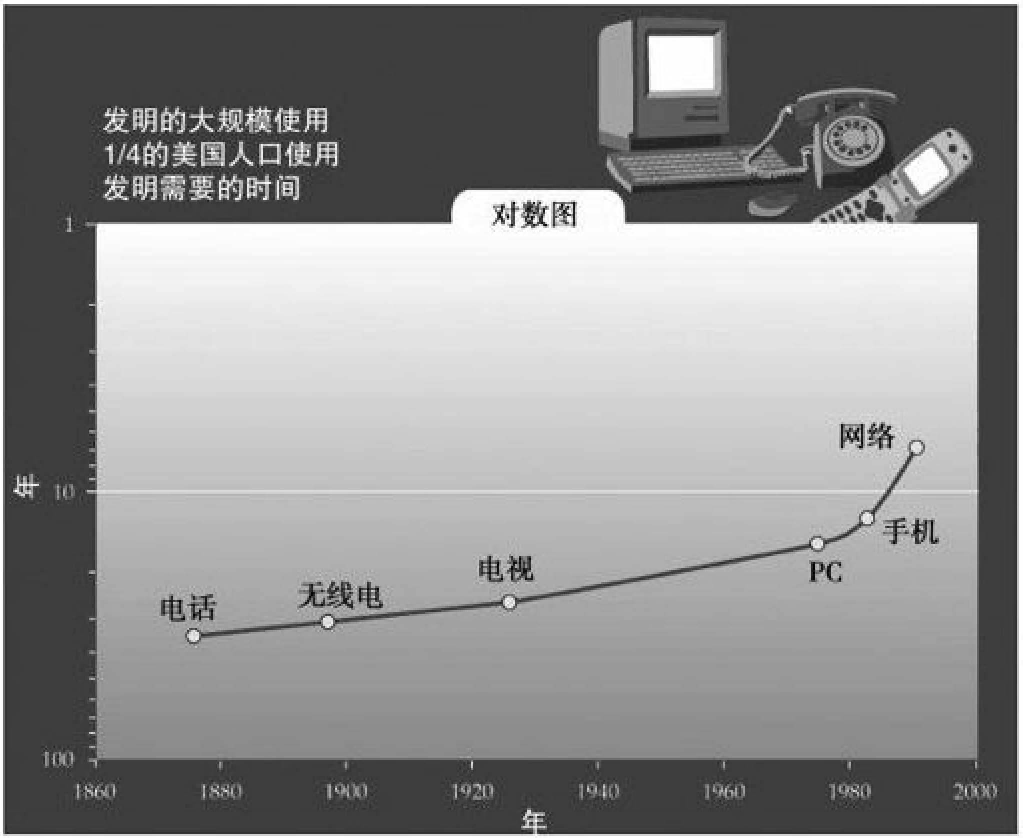

美国
手机用户数量的估计值
对数图
用户（百万）
年

图 2-4

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——[illegible]1905[illegible]

[illegible]

——[illegible]·[illegible]

[illegible]470[illegible]16[illegible]

[illegible]

[illegible]7[illegible]

1[illegible]·[illegible]

2[illegible]

3[illegible]·[illegible]

4[illegible]

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5□□
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6□□
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7□□□□□□□□□□□□□5%□10%□□□□□□□□□□□□□□——□□□□□□
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19□□□
□□□□□□□1877□□□□□·□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
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□33□/□□□□□□□□□RCA□□□□45□/□□□□□□□□□□□□□□□20□□60□
□□□□□20□□70□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
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□”□□□
□□□□□□——□□□1825□□□□□□·□□□□□□□□□□□□□□□□□□□□□□□

[illegible]19[illegible]80[illegible]

[illegible]“[illegible]”[illegible]

[illegible]

[illegible]2[illegible]

[illegible]

[illegible]8[illegible]11[illegible]15[illegible]·[illegible]1455[illegible]

[illegible]20[illegible]

[illegible]20[illegible]CD-ROM[illegible]

[illegible]CD-ROM[illegible]DVD[illegible]33[illegible]·[illegible]

[illegible]60[illegible]22[illegible]VGA[illegible]

[illegible]120:1[illegible]600[illegible]1000[illegible]DPI[illegible]1/10[illegible]

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[illegible]5[illegible]

[illegible]

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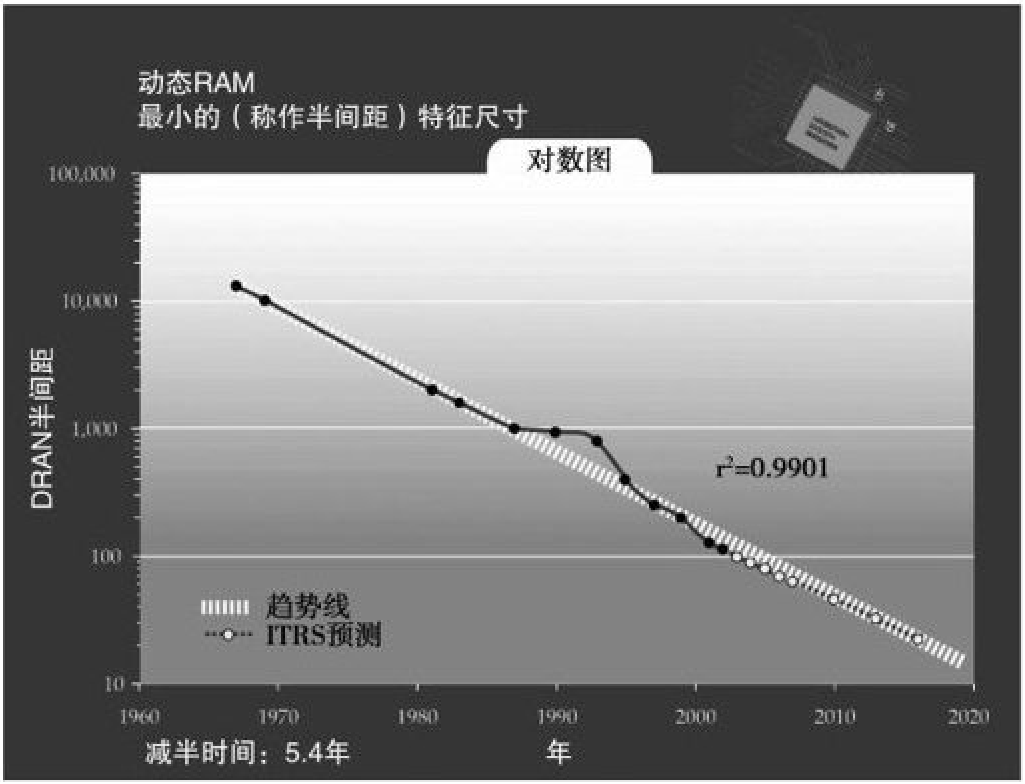
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[illegible]

——E.W.Dijkstra

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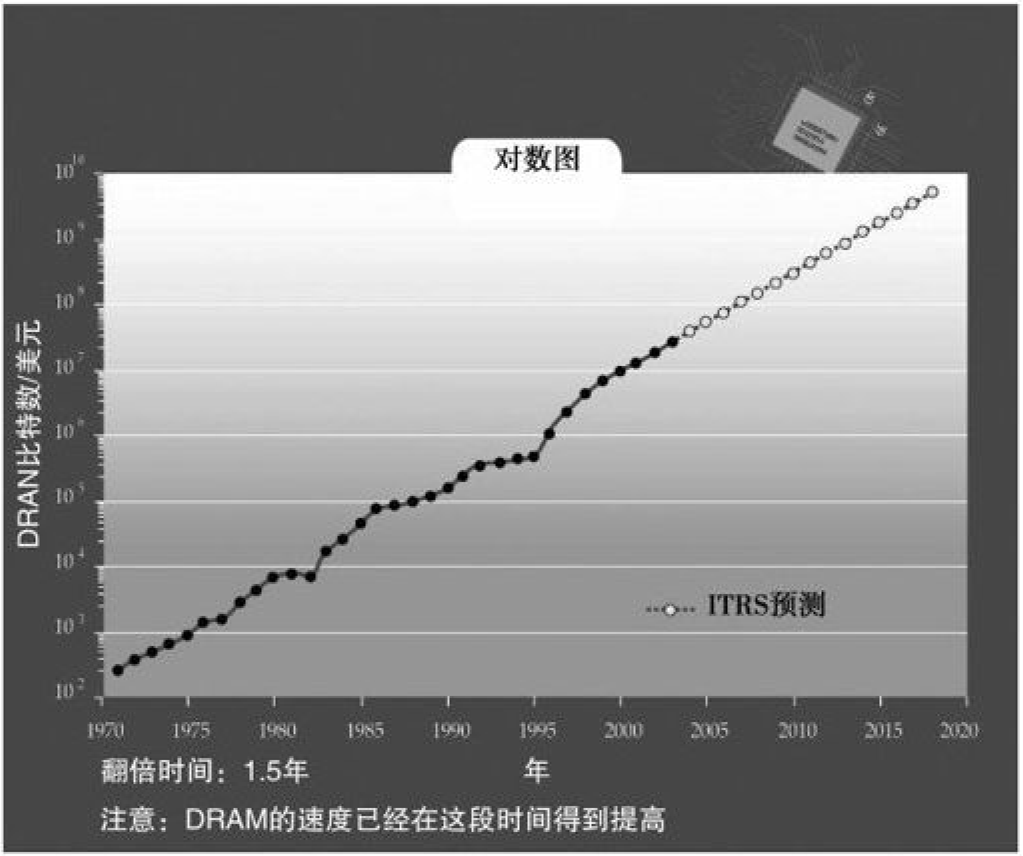
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[illegible] 2-6

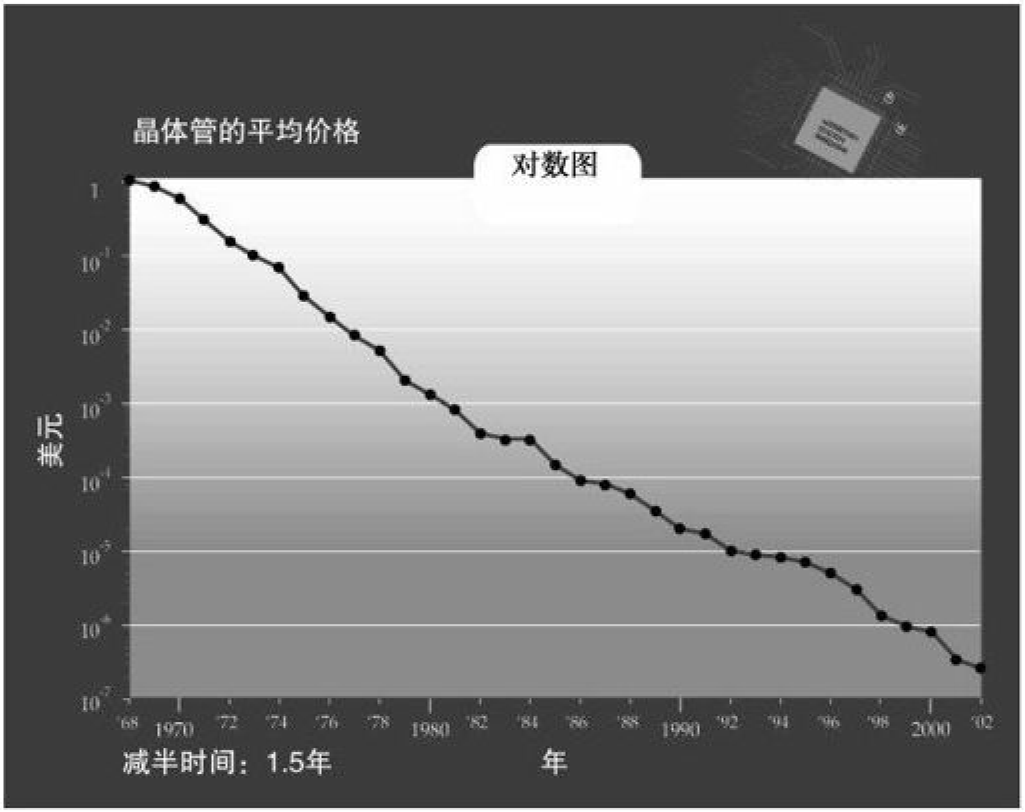
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2018[illegible]

[illegible]DRAM[illegible]1[illegible]DRAM[illegible]
[illegible]1.5[illegible][23][illegible]2-7[illegible]



□ 2-7

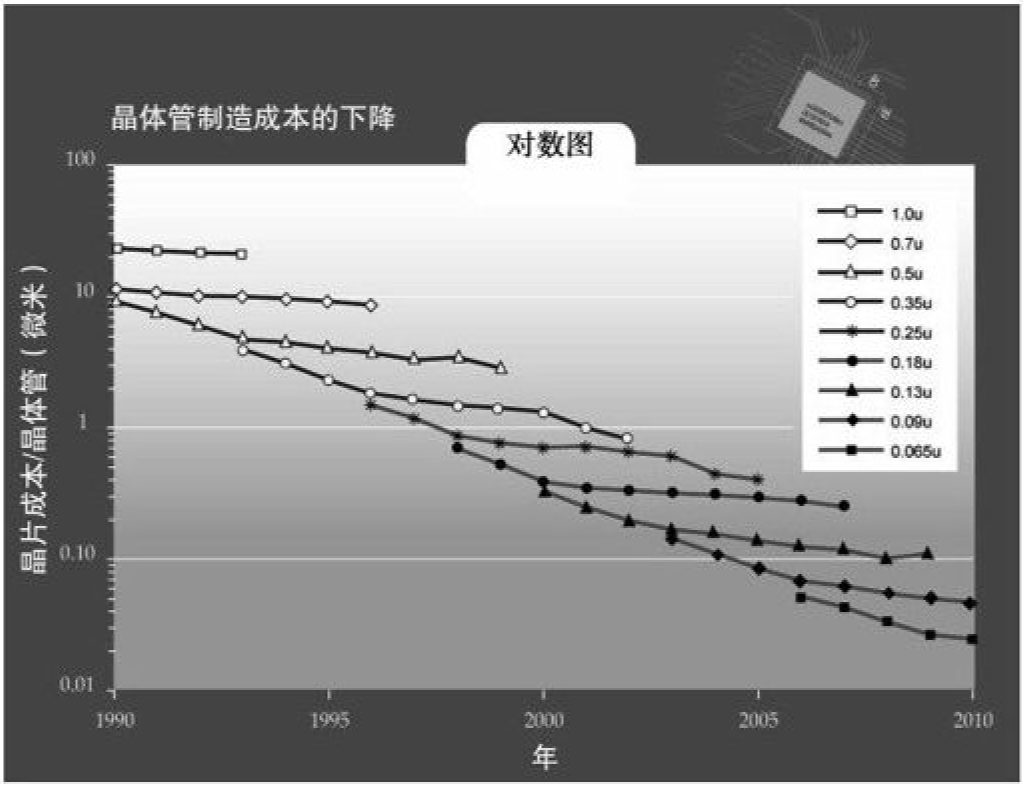
□□□□□□□□□□□□□□□□1968□1□□□□□1□□□□□2002□1□□□□□□□□1000□□□□□□□□DRAM□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□DRAM□□1.6□□□□2-8□[24]□



[illegible] 2-8

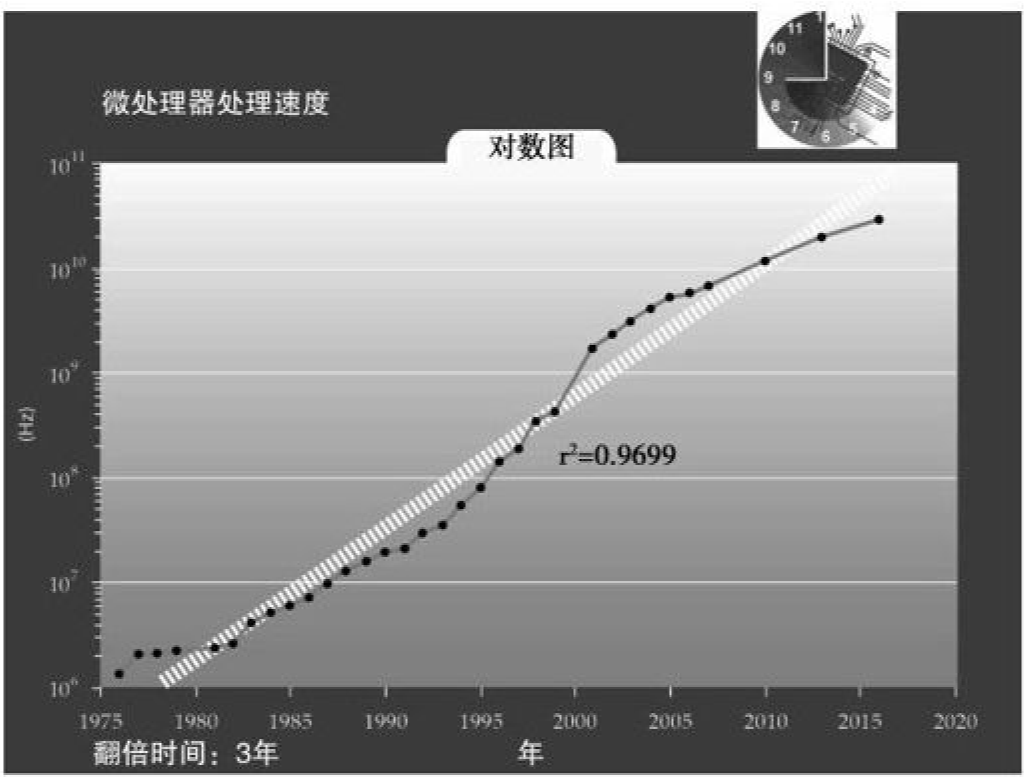
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[illegible]·[illegible]“[illegible]”[illegible]“[illegible]”[illegible]30[illegible]2-10[illegible]——[illegible][26][illegible]



晶体管制造成本的下降
对数图
晶片成本/晶体管（微米）
100
10
1
0.10
0.01
1.0u
0.7u
0.5u
0.35u
0.25u
0.18u
0.13u
0.09u
0.065u
1990
1995
2000
2005
2010
年

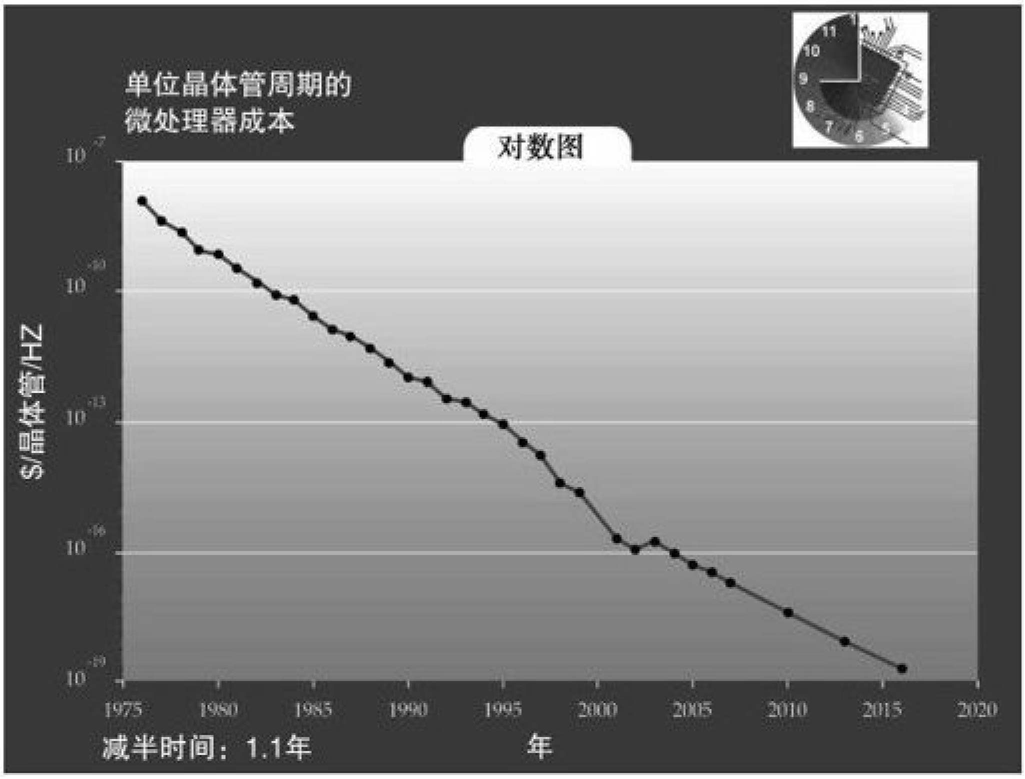
图 2-9



微处理器处理速度
对数图
(Hz)
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
r^2=0.9699
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
翻倍时间：3年
年

图 2-10

[illegible]1.1[illegible]2-11[illegible][27][illegible]



[illegible] 2-11

[illegible]2-12[illegible][28][illegible]

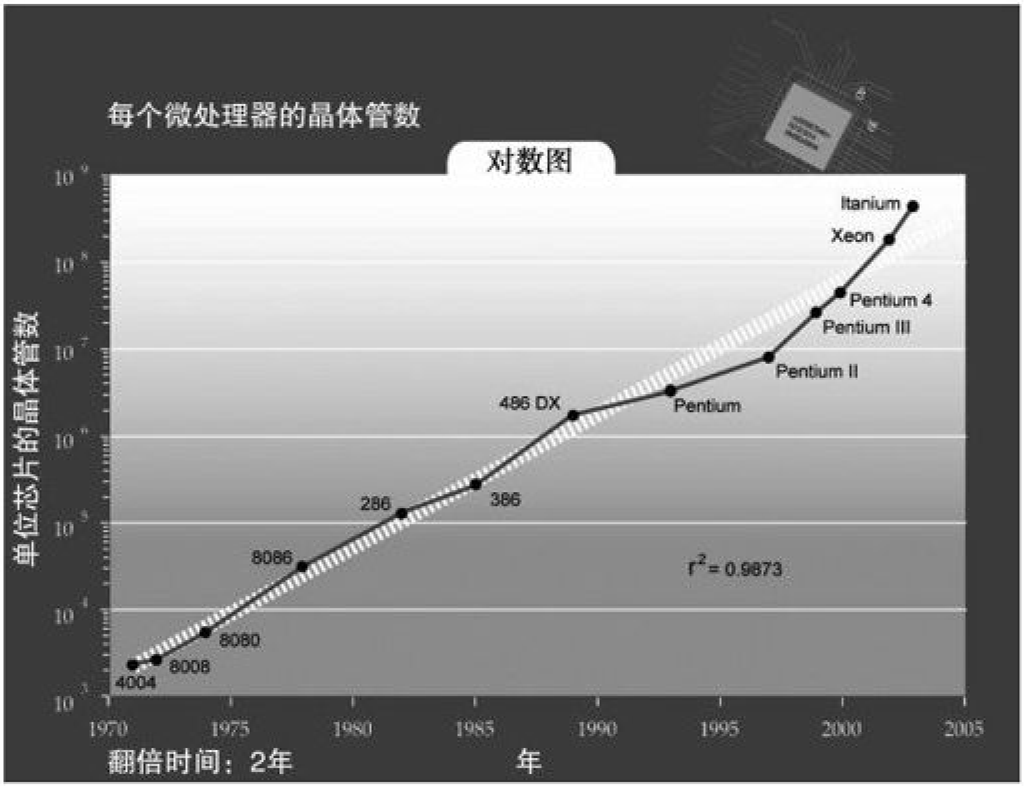
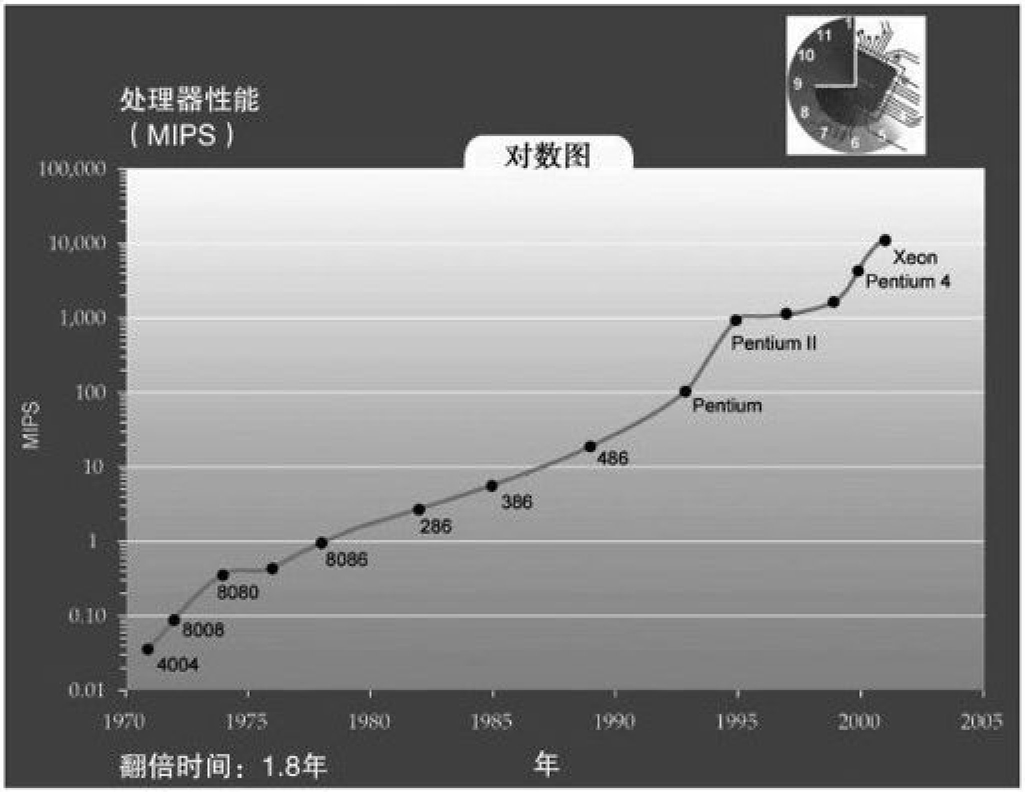


图 2-12

每单位的MIPS成本下降速度更快，其翻倍时间为1.8年，我们可以从图2-13中看到，在当下以及可预见的未来，这种速度还会持续提升[29]。



□　2-13

□□□□□40□□□□□□□□□□□□□□□□□□□□□□□□1960□□□□□□MIT□□□□□□□□□□□□1967□□□□□□□□□□□□□□IBM 7094□□□□32K□□□36bit□□□□□□□□□□□□1/4 MIPS□2004□□□□□□□□□□2000□□□□□□□□□G□RAM□□□□□□2000MIPS□MIT□□□□□□□□□□□□□□□□□□□□□□□□□□MIPS□□□□□MIT□□□□800□□□□□□2-1□□□

表　2-1

度量标准	IBM 7094（约 1967 年）	笔记本电脑（约 2004 年）
处理器速度（MIPS）	0. 25	2 000
主存（K Bytes）	144	256 000
近似成本（2003 美元）	11 000 000	2 000

□□□□□□□□□□□□□□□2000MIPS□□□□□□□1967□□□□□□□□224□□□□□□□□□□□37□□□□24□□□□□18.5□□□□□□□□□□2004□□□

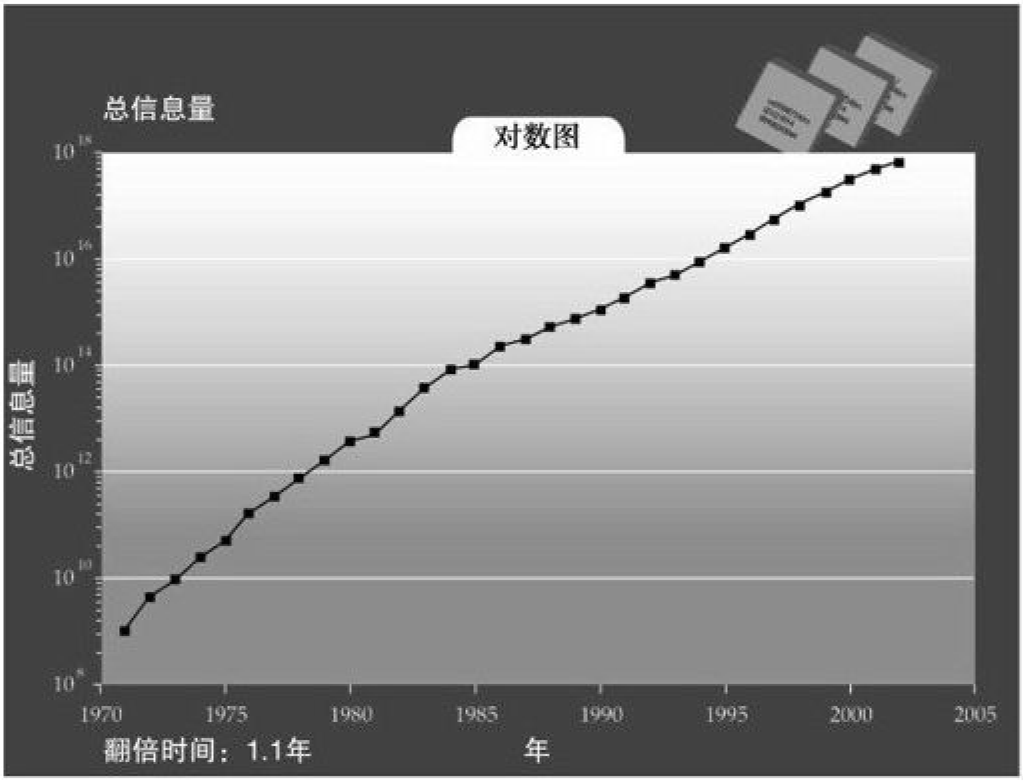
□□□□□RAM□□□□□□□2000□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

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表 2-2

翻倍（或减半）时间[33]	
动态 RAM "半间距" 特征尺寸（最小芯片特征）	5.4 年
动态 RAM（单位美元生产的比特数）	1.5 年
晶体管平均价格	1.6 年
每个晶体管周期的微处理器成本	1.1 年
总信息量	1.1 年
以 MIPS 衡量的处理器性能	1.8 年
中央处理器的晶体管	2.0 年
微处理器时钟速度	3.0 年



[illegible] 2-14

[illegible]

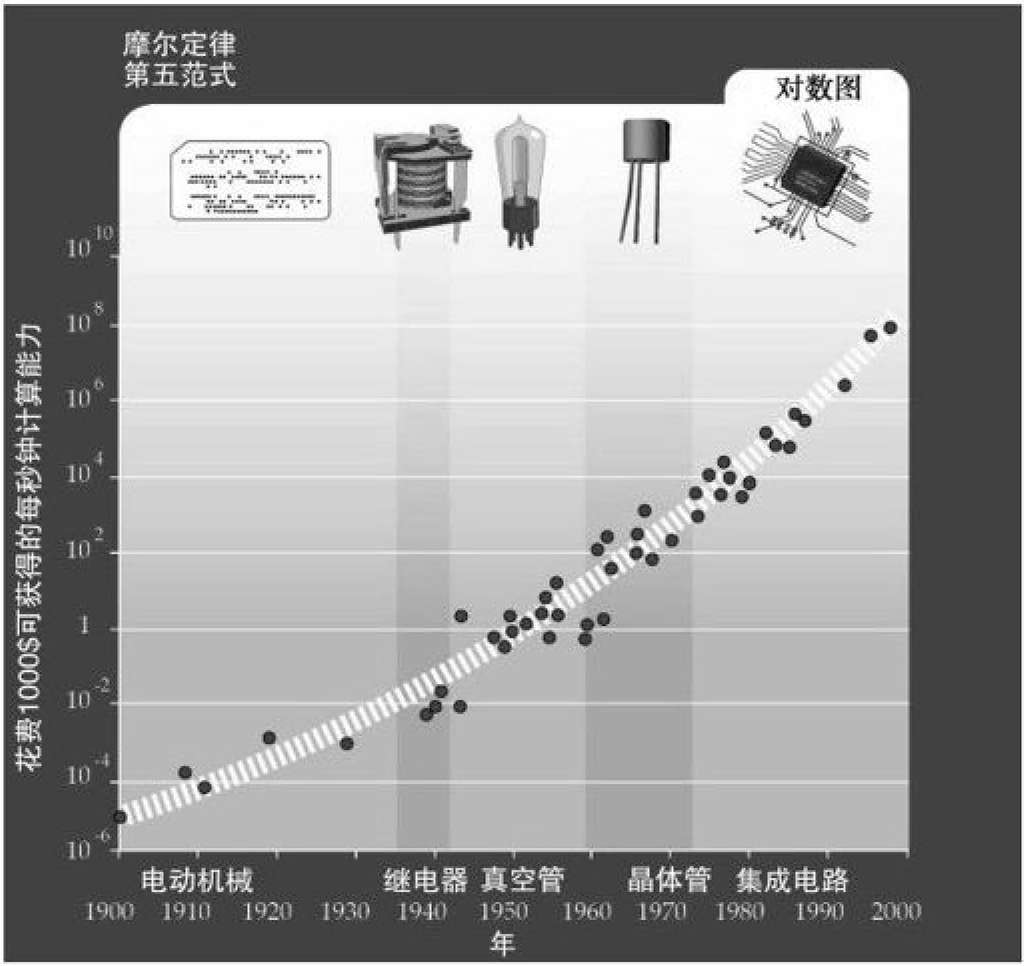
[illegible][34][illegible]

[illegible][35]

[illegible]1000[illegible]49[illegible]20[illegible]2-15[illegible]

[illegible]2-15[illegible]——[illegible]S[illegible]2020[illegible]

[illegible]



摩尔定律
第五范式
对数图
花费1000$可获得的每秒钟计算能力
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
1
10^{-2}
10^{-4}
10^{-6}
电动机械
继电器
真空管
晶体管
集成电路
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
年

[illegible] 2-15

[illegible]

[illegible]6[illegible]“[illegible]”[illegible]

□□□□□2-15□□□□□□□□□□□□□□□□□□□□□[36]□□□□□□□□□□□□□

□□□

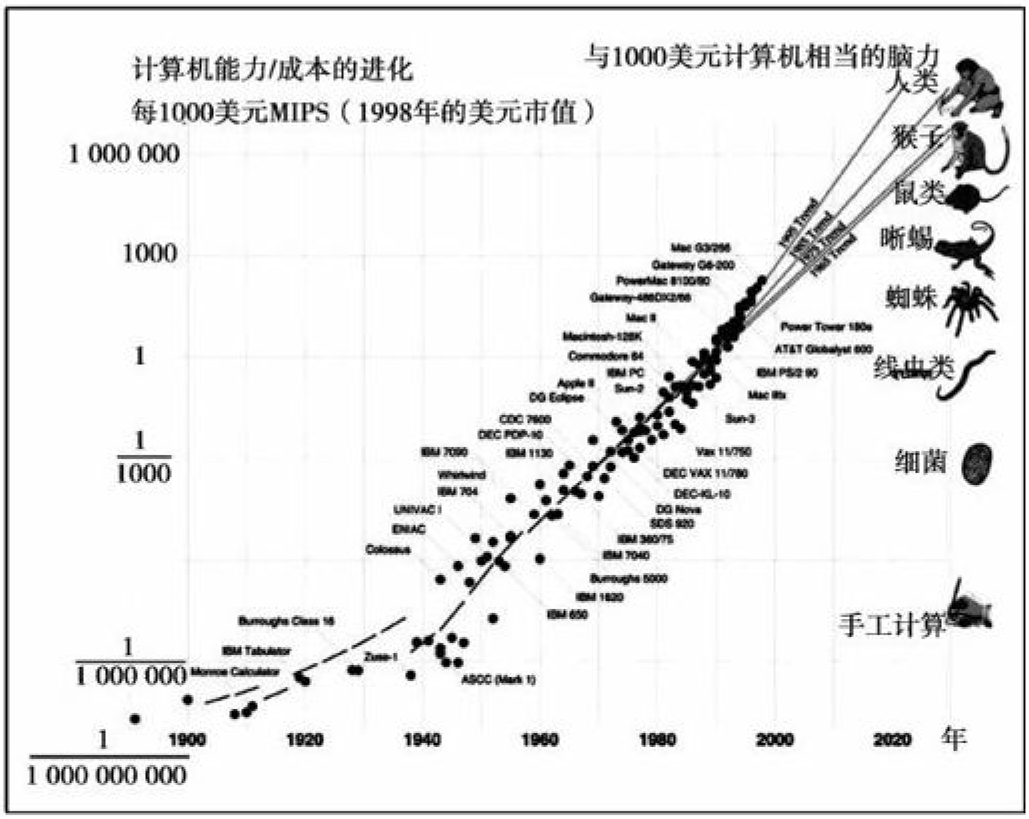
□2-16□□□□□□□□□□20□□□□□□□□□□□□□20□□□□□□□□□□□□□□

□□□□□□□□□□□[37]□

□□·□□□□□□□□□□□□□□2-16□□□□□□□□□□□□□□□□□□□□□□□□

□□□

□[38]□

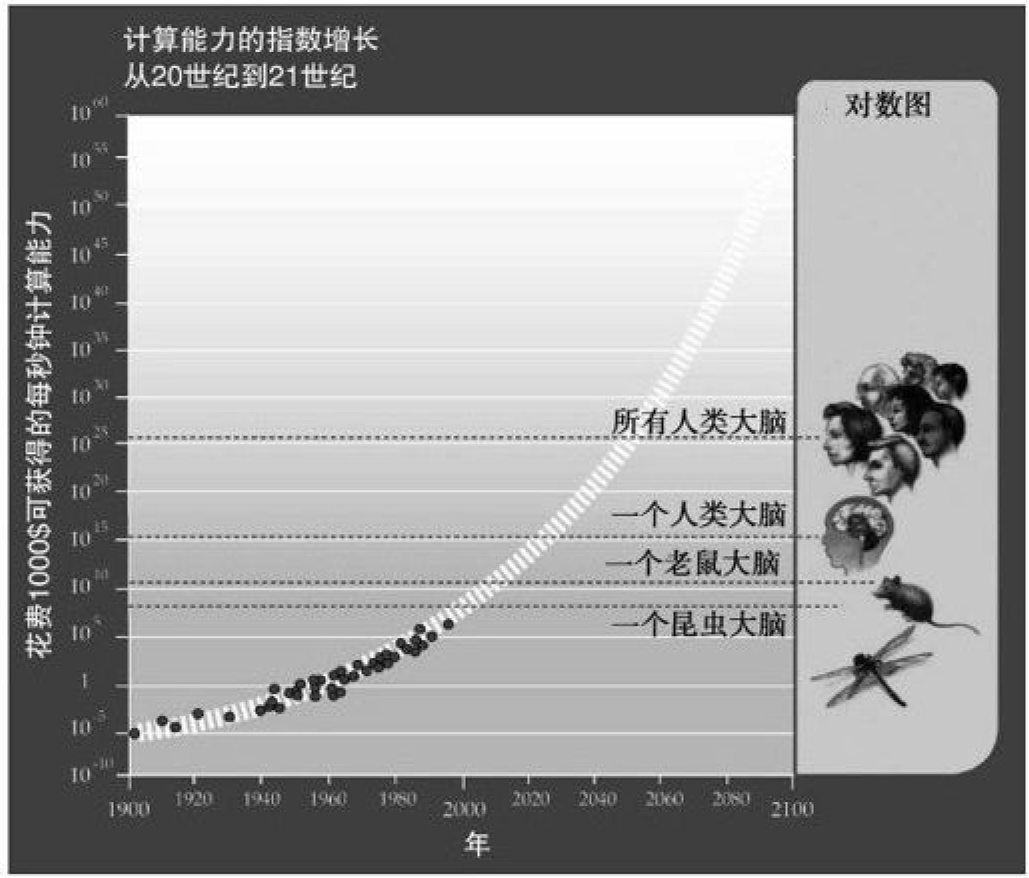


□ 2-16

□□□□□□22□□□□□□□□□□□□□□□□□2-17□□□□□□□□□□2010□

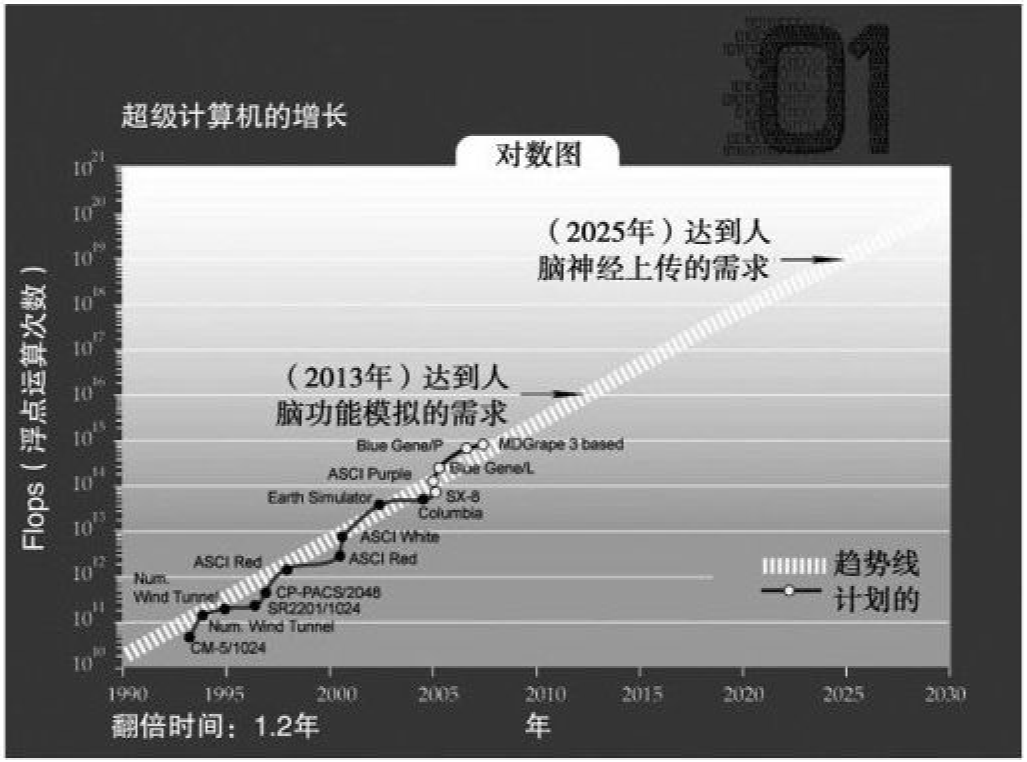
□□□□□□□□□□□□□□□□2020□□□□□□□□□□□□□□□□□□□□□□□□□

□□□□□□□□□□□□□□□□□□3□□□□□□□□□□□□□[39]□



□ 2-17

□□90□□□□□□□□□□MIPS/□□□□□□□□□□□□1□MIPS/□□□□□□5□□□[40]□



[illegible] 2-18

IBM[illegible]/P[illegible]100[illegible]10[illegible]2007[illegible][41][illegible]10^{15}[illegible]1/10——[illegible]10^{16}[illegible]3[illegible]10[illegible]1016[illegible]

[illegible]“[illegible]”[illegible]

[illegible]200[illegible]/[illegible]100[illegible]wings[illegible]3[illegible]

[illegible]3[illegible]21[illegible]S[illegible]

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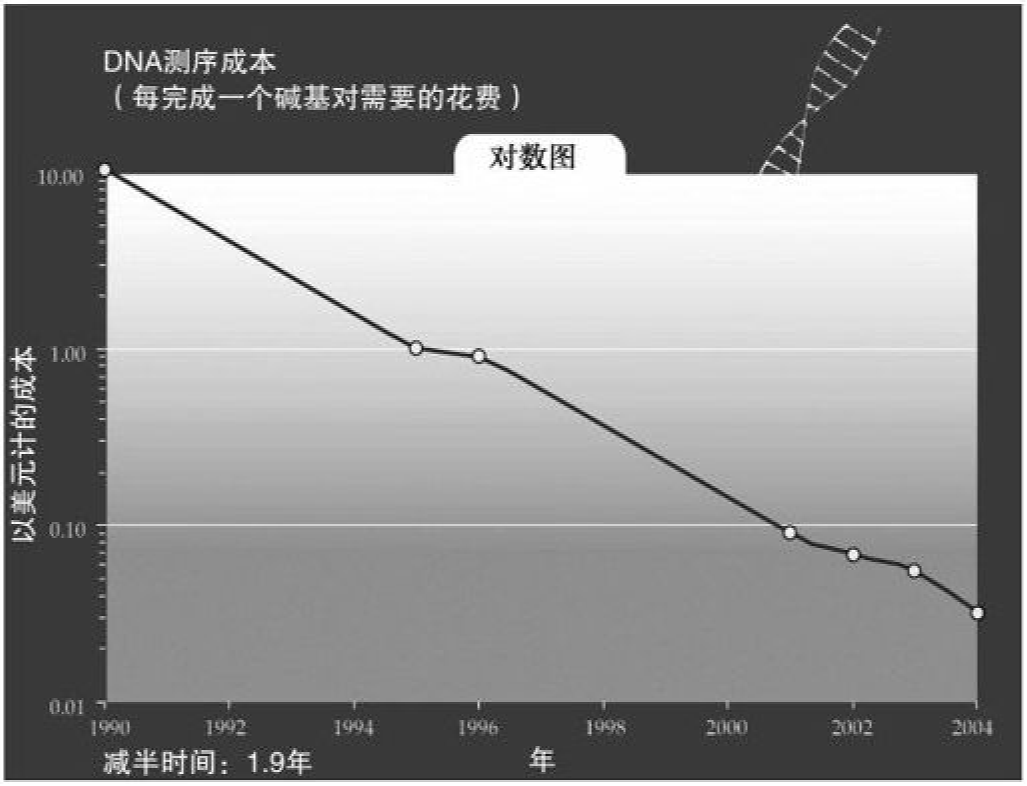
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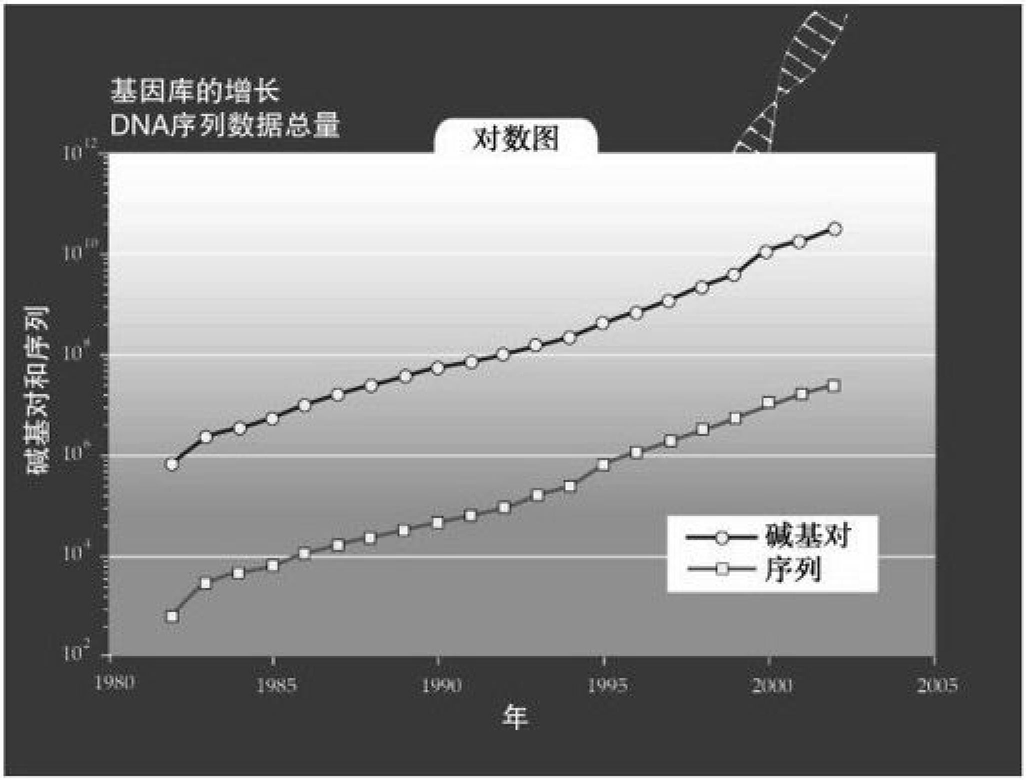


□ 2-19

□□□□□DNA□□□□□□□□□□□□□□□□□2-20□[45]□□□□□□□□□□□□

SARS□□DNA□□□□□——□SARS□□□□□□□□□□□□□31□□□HIV□□DNA

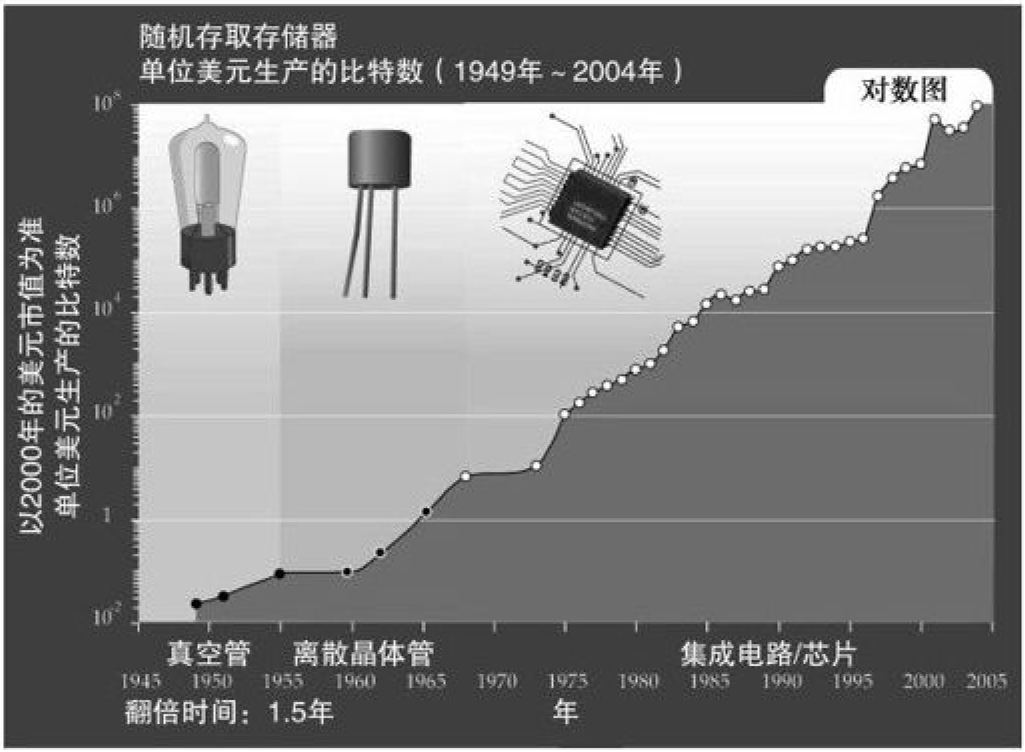
□□□□□□□□□□□15□□□□[46]□



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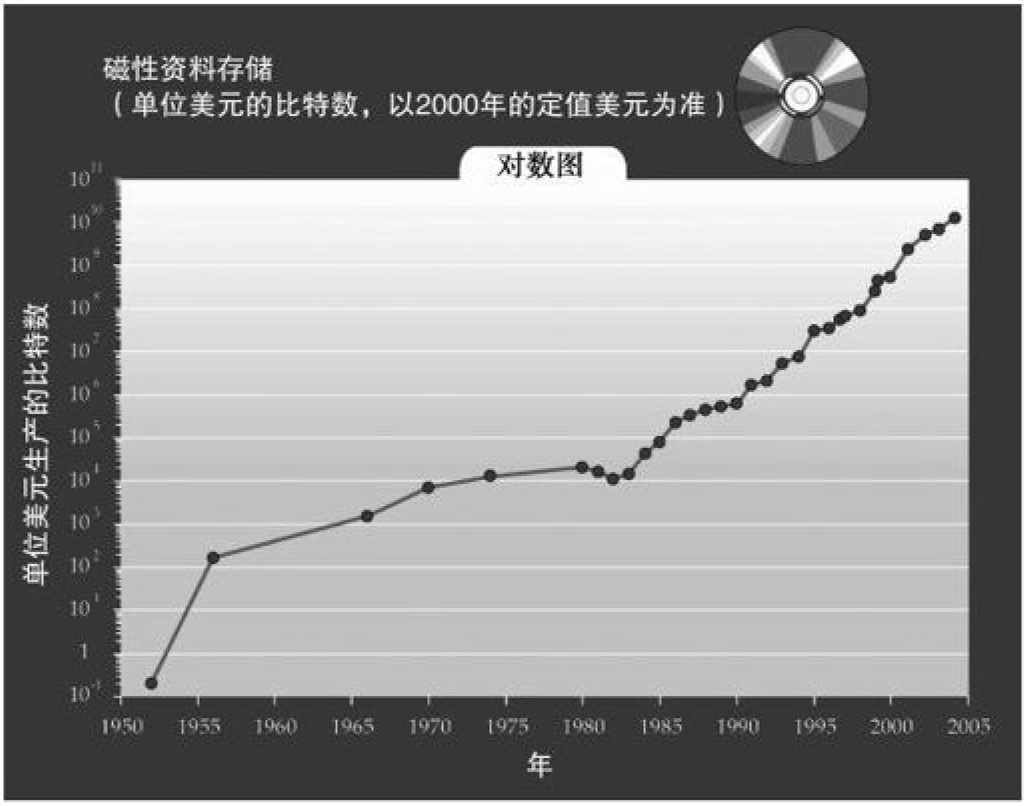
[illegible][47][illegible]


随机存取存储器
单位美元生产的比特数（1949年～2004年）
对数图
以2000年的美元市值为准
单位美元生产的比特数
真空管
离散晶体管
集成电路/芯片
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005
翻倍时间：1.5年
年

[illegible] 2-21

[illegible]2-22[illegible]

[illegible][48][illegible]



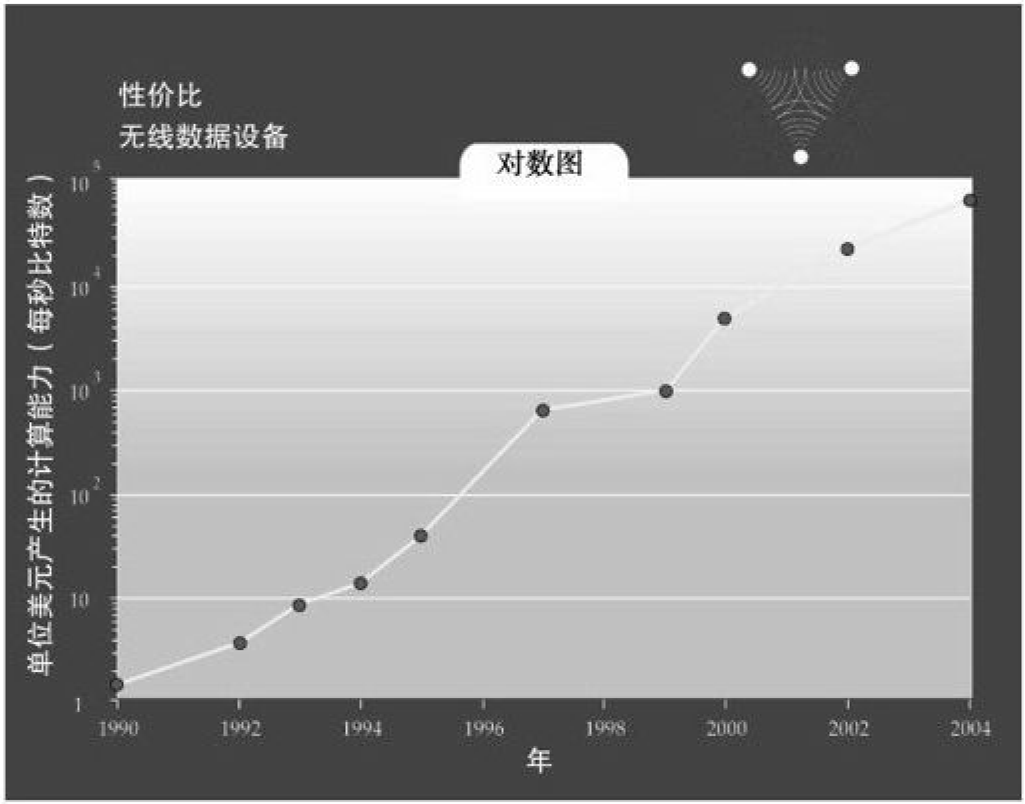
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[illegible][49][illegible]

[illegible]10

[illegible]11[illegible]2-23[illegible]



[illegible] 2-23

[illegible]2-24[illegible]2-25[illegible]20[illegible]90[illegible]20[illegible]80[illegible]APPANET[illegible][50][illegible]

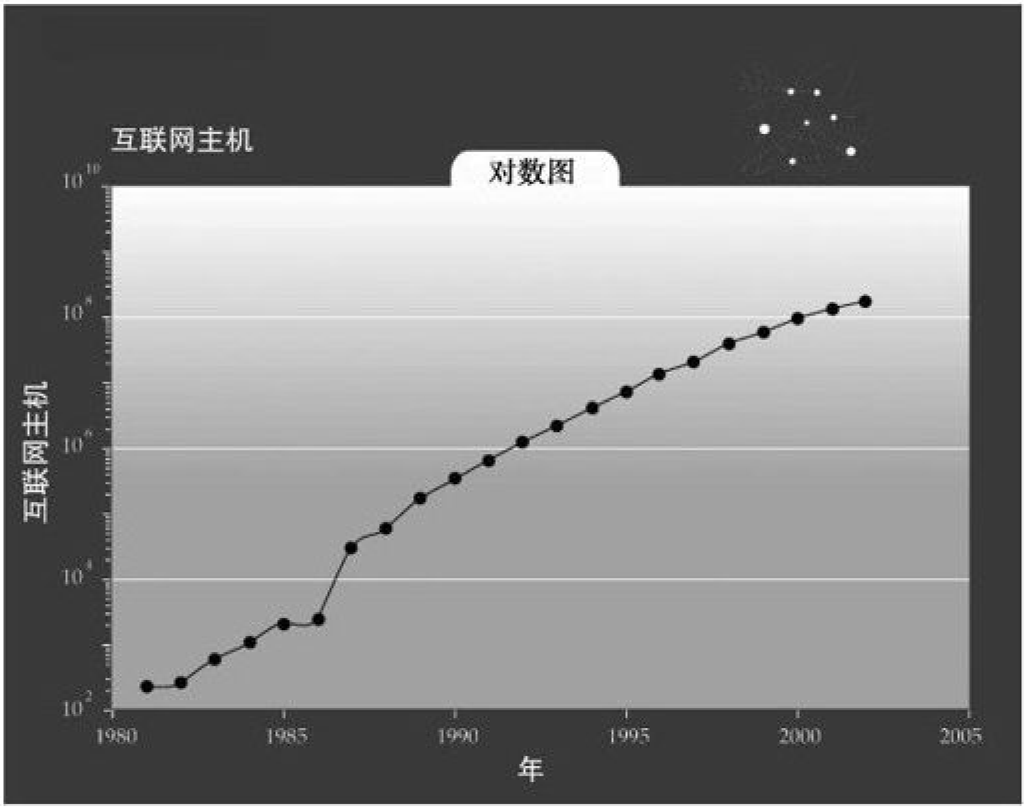
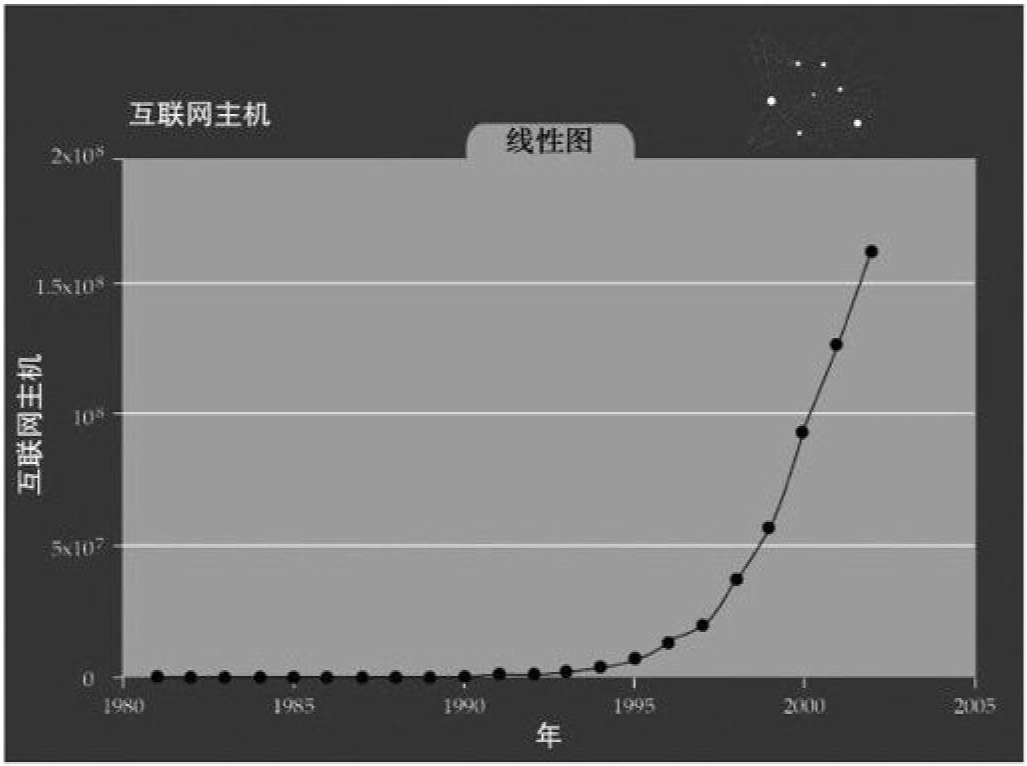


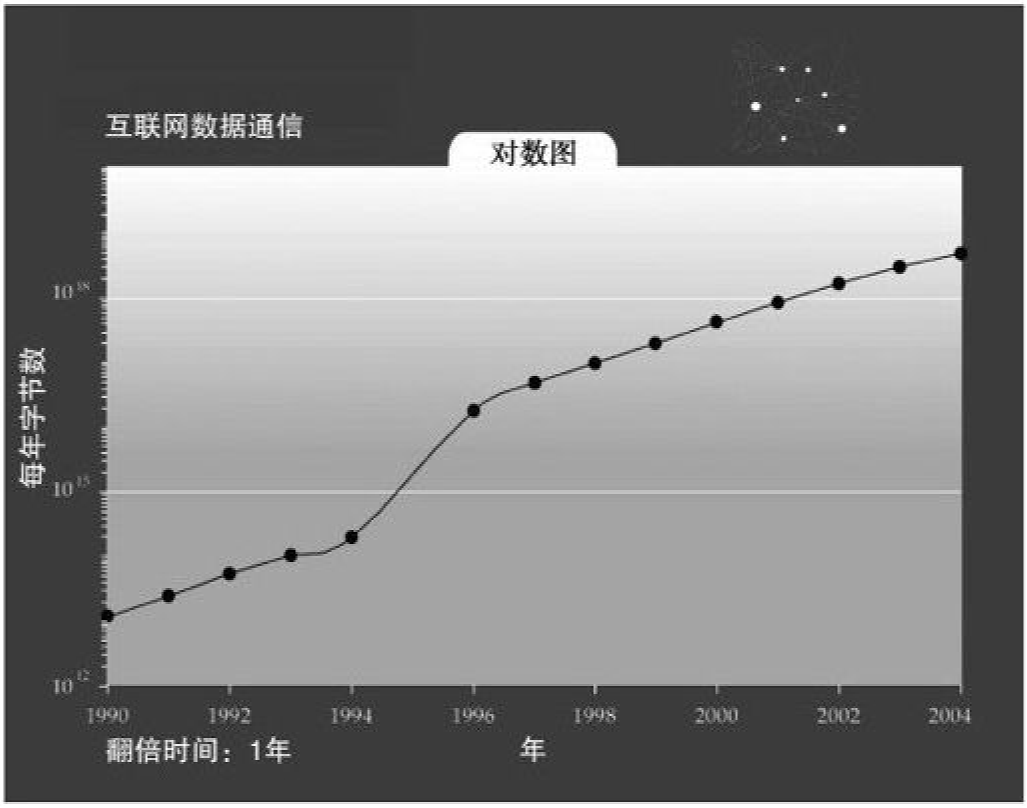
图 2-24

图2-25显示了以线性坐标表示的相同数据[51]：


互联网主机
线性图
2x10⁸
1.5x10⁸
10⁸
5x10⁷
0
互联网主机
1980
1985
1990
1995
2000
2005
年

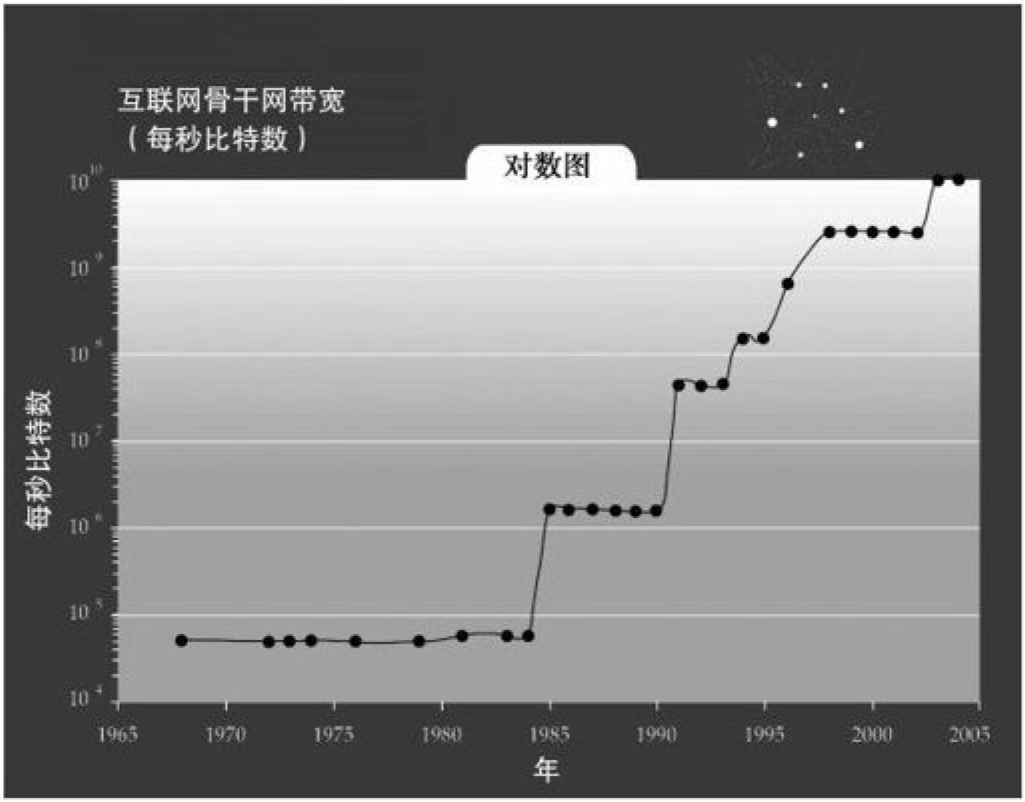
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[illegible][52][illegible]2-26[illegible]



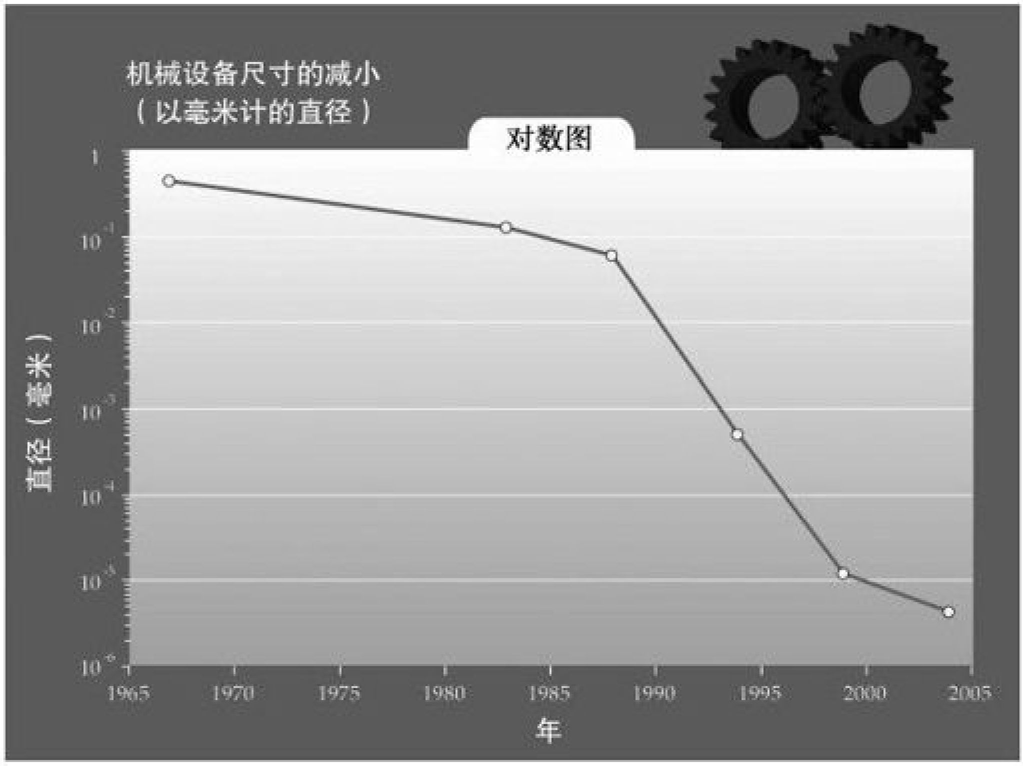
[illegible] 2-26

[illegible]2-27[illegible]2-27[illegible]“[illegible]”[illegible]S[illegible][53][illegible]



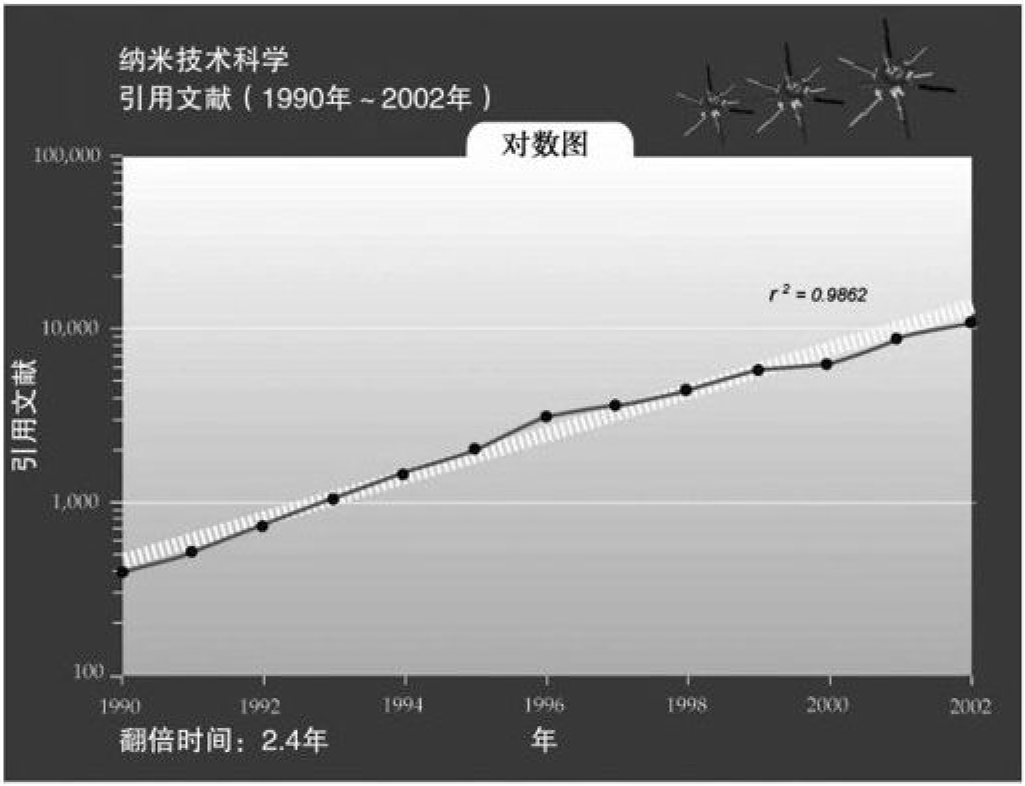
[illegible] 2-27

[illegible]21[illegible]10[illegible]1/4[illegible]2-28[illegible][54]



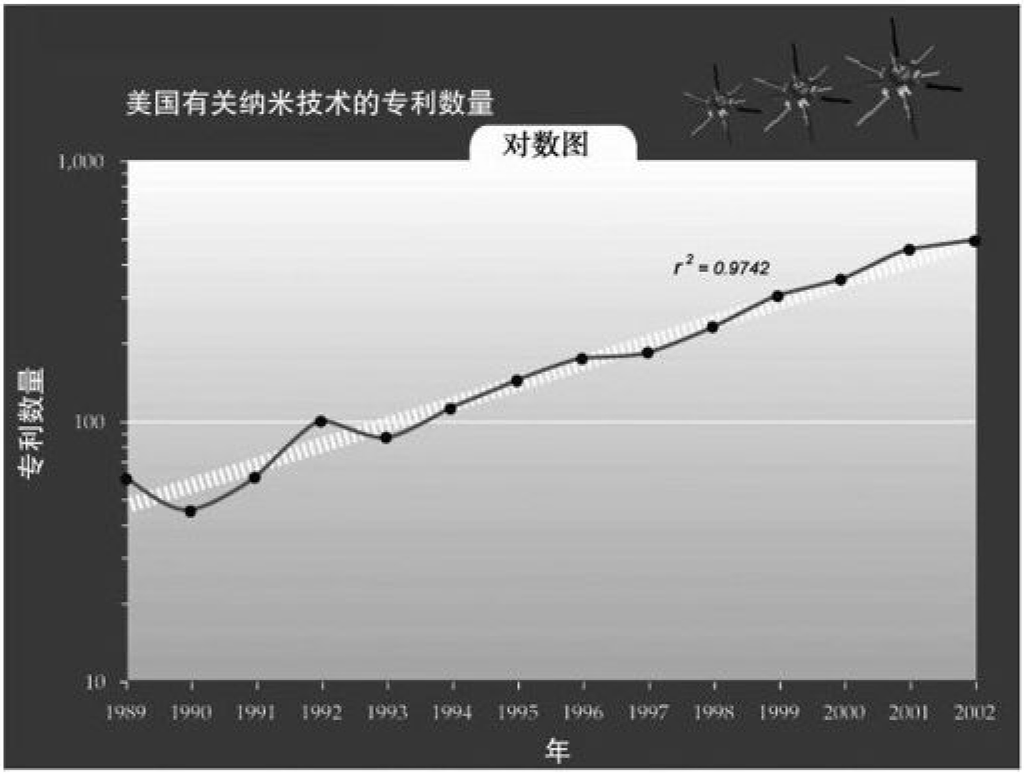
□ 2-28

□□100□□□1□□□1□□10□□□□□□□□2-29□□[55]□□□□□□□□□□□□□□□□□□□□□□


纳米技术科学
引用文献（1990年～2002年）
对数图
100,000
10,000
1,000
100
引用文献
r^2 = 0.9862
1990
1992
1994
1996
1998
2000
2002
翻倍时间：2.4年
年

□ 2-29

□□□□□□□□□□□□□□□□□□□□□□□□□2-30□[56]□



美国有关纳米技术的专利数量
对数图
1,000
100
10
专利数量
r^2 = 0.9742
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
年

[illegible] 2-30

[illegible]

[illegible]

[illegible]

[illegible]2[illegible]DNA[illegible]20[illegible]

[illegible][58][illegible]

[illegible]·[illegible]A New Kind of Science[illegible]“[illegible]”[illegible][59][illegible]

[illegible]

[illegible]·[illegible]·[illegible]1948[illegible][60][illegible]“[illegible]”[illegible]1967[illegible]·[illegible][61][illegible]1935[illegible]1941[illegible]

[illegible]·[illegible]20[illegible]80[illegible]“[illegible]”[illegible]

[illegible]

20[illegible]80[illegible]·[illegible]

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[illegible]

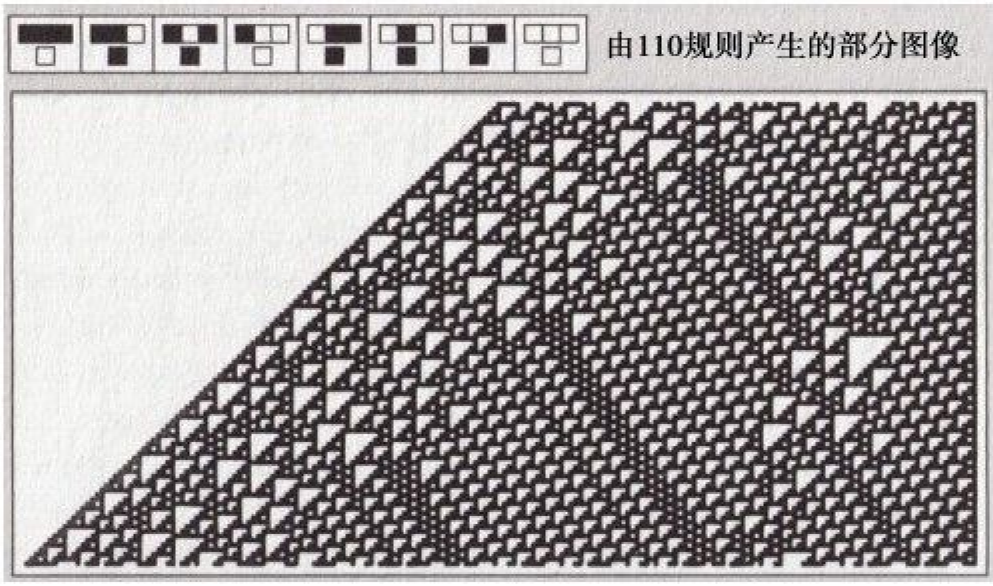
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[illegible][64][illegible][65][illegible]3[illegible]

[illegible] 110 [illegible] 110 [illegible] 8 [illegible] 3 [illegible] 8 [illegible] 28 [illegible] 256 [illegible] 256 [illegible] 128 [illegible] 128 [illegible] 64 [illegible] 2-31 [illegible] y [illegible]

[illegible]

[illegible] 110 [illegible] 2-31 [illegible]



[illegible] 2-31

[illegible]——[illegible][66][illegible]

[illegible]“[illegible][67]”

[illegible]110[illegible][68][illegible]

[illegible]3[illegible]1[illegible]

[illegible]10[illegible][69][illegible]

[illegible]

[illegible]

[illegible]1[illegible]Fortran[illegible]

[illegible]

[illegible]

[illegible]

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[illegible]

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[illegible]“[illegible]”[illegible]

[illegible]——[illegible]

[illegible]——[illegible]10[illegible]

[illegible]

[illegible]

[illegible][72]。

[illegible]

[illegible]“[illegible]—[illegible]”[illegible]

[illegible]

[illegible]·[illegible]19[illegible]

[illegible]·[illegible]1950[illegible]7[illegible][73][illegible]“[illegible]”[illegible][74][illegible]

[illegible]“[illegible]”[75][illegible]110[illegible][76][illegible]

[illegible]

[illegible]2004[illegible]

[illegible]

[illegible]2004[illegible]

[illegible]·[illegible]

[illegible]1000[illegible]100[illegible]

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[illegible][77][illegible]

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[illegible]

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[illegible]

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[illegible]

[illegible]

——[illegible]·[illegible]·[illegible]1903[illegible]

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[illegible]

——[illegible]·[illegible]CEO[illegible]

[illegible]80[illegible]——[illegible]

[illegible]80[illegible]

[illegible]

[illegible]

[illegible]“[illegible]”[illegible]1974[illegible]OCR[illegible]30[illegible]1974[illegible]2000[illegible]2003[illegible]100[illegible][79][illegible]

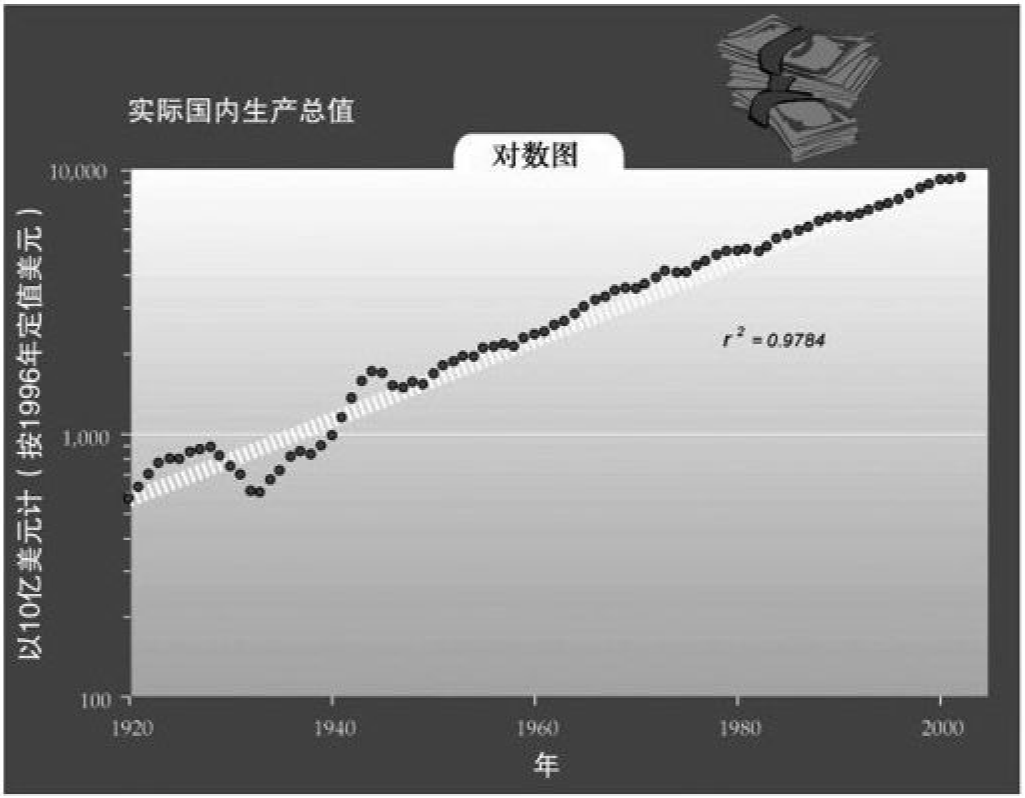
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[illegible]

[illegible]“[illegible]”[illegible]

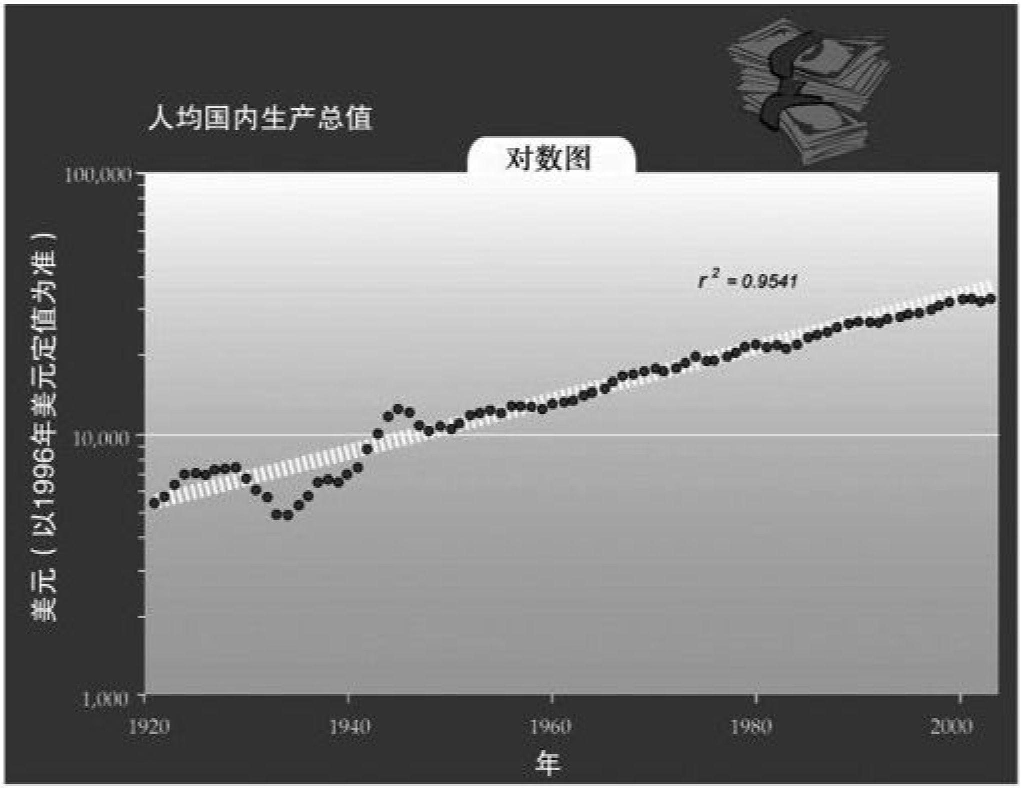
[illegible]2042[illegible]3[illegible]65[illegible]30[illegible]GNR[illegible]1.7%[illegible]15[illegible]

□□
□□□□□□□□□□□□□□2-32□□□[81]



□ 2-32

□□□□□□GDP□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□2-33□□[82]



[illegible] 2-33

[illegible]“[illegible]”[illegible]

[illegible]2004[illegible]2004[illegible]4%[illegible][83][illegible]6%[illegible]5%[illegible]1990[illegible]4.70[illegible]2001[illegible]2.7[illegible]2015[illegible]2000[illegible]

[illegible]“[illegible]”[illegible]

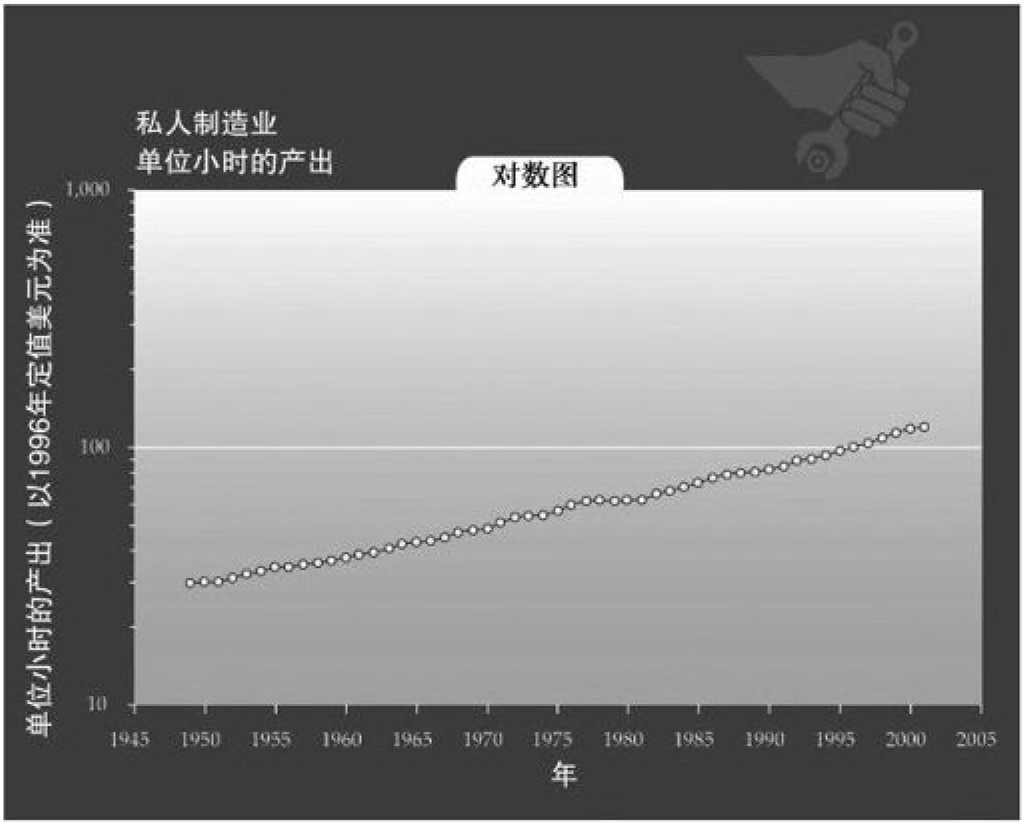
□□□□□□□□□□□□□□□□□1000□□□□□□□□□□□10□□1000□□□□□□□□□□□□□□□□□1000□□5□□□□□□□□□□□□□□5□□□

□□□□□□□□□□□□□□□□□□□□□□□□□□□□1□□□□□□1□□□·□□□□□□□□□□□□□□□□□·□□□□□□□□□□□□□□□□□□□□□□□□□□□□20□□□□□1.5%□□□□□[84]□□

□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□0.5%□□□□□[85]□□□1□□□□□□□□□□□□□□□□□□□□□□□□

□□□1994□□□□□□□□□□□□1.6%□□□□□□□□□□□□□2.4%□□□□□□□□□□□□□□□1995□□1999□□□□□□□□□□□□□□4.4%□□□□□□□□□□□□□□□□□6%□□□□□□□□2004□□□□□□□□□□□□□□□□□□□□□□□□□□□4.6%□□□□□□□□□□□□□□5.9%[86]□

□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□2-34□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□[87]□□□□□□□□□□□□□□□□



□ 2-34

□□□□——□□□

“□□1846□□”

——□Scientific American□□1853□

□□“□□”□

40%[illegible]50%[illegible]17%[illegible][88][illegible]

20[illegible]90[illegible]21[illegible]

[illegible]IT[illegible]20[illegible]30[illegible]

[illegible]BP Amoco[illegible]2000[illegible]1[illegible]1991[illegible]10[illegible]1[illegible]1[illegible]

[illegible]2-3[illegible]

表 2-3　软件性价比的指数增长[89]

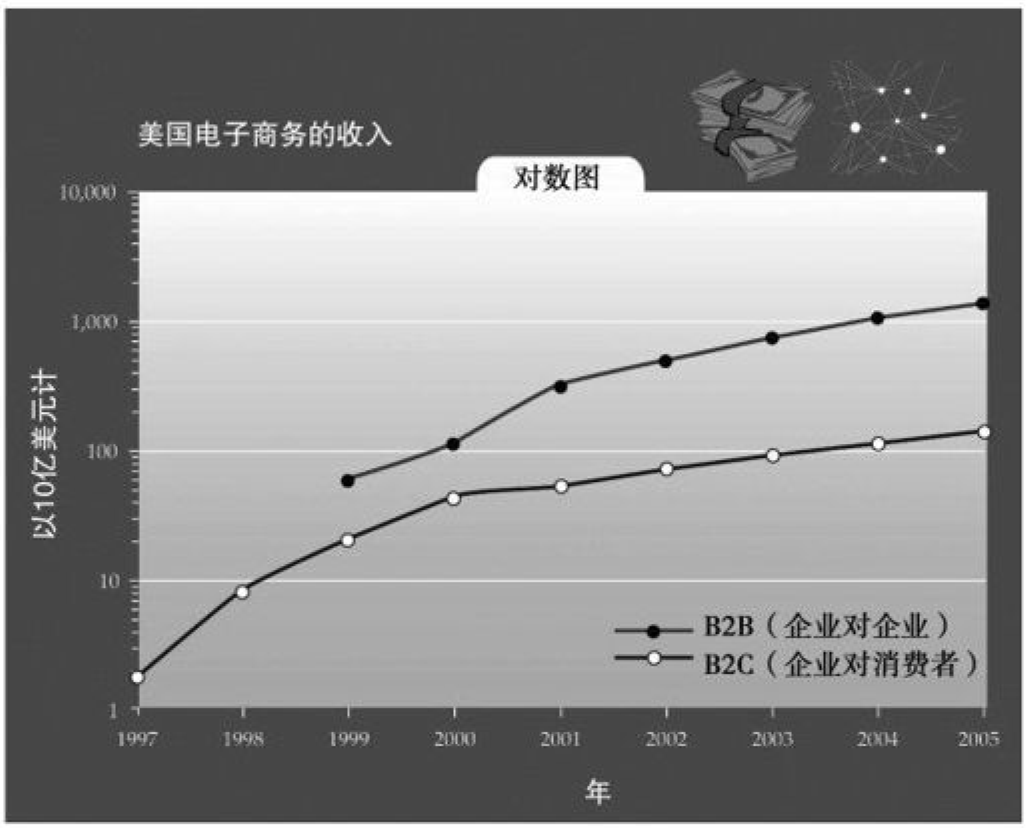
例如：自动语音识别软件

	1985	1995	2000
价格	5 000 美元	500 美元	50 美元
词汇多少（字数）	1 000	10 000	100 000
连续语音	否	否	是
用户培训时间（分钟）	180	60	5
精度	差	一般	好

[illegible]20[illegible]90[illegible]

□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
□□□□□□□□□□□□□□□□□□□□□□□□“□□□□”□□□□□□□□□□□□
□□□□□□□□□□□□□□□□□S□□□□□□□□□

□□□□□□□□□□□□□□□□□□□□□□□□□□□□B2B□B2C□□□□
□□□□□□□□□□□□□□□□□□□2-35□□□□B2C□□□□□□□□□□□
1997□□18□□□□□2002□□700□□□B2B□□□□□1999□□560□□□
□□□□2002□□4820□□□[90]□□□2004□□□□□□□□1□□□□□□□□□□
□□□□□□□□□□□□□□□□□□□□□□□□□



□ 2-35

□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
□□

[illegible]eBay[illegible]

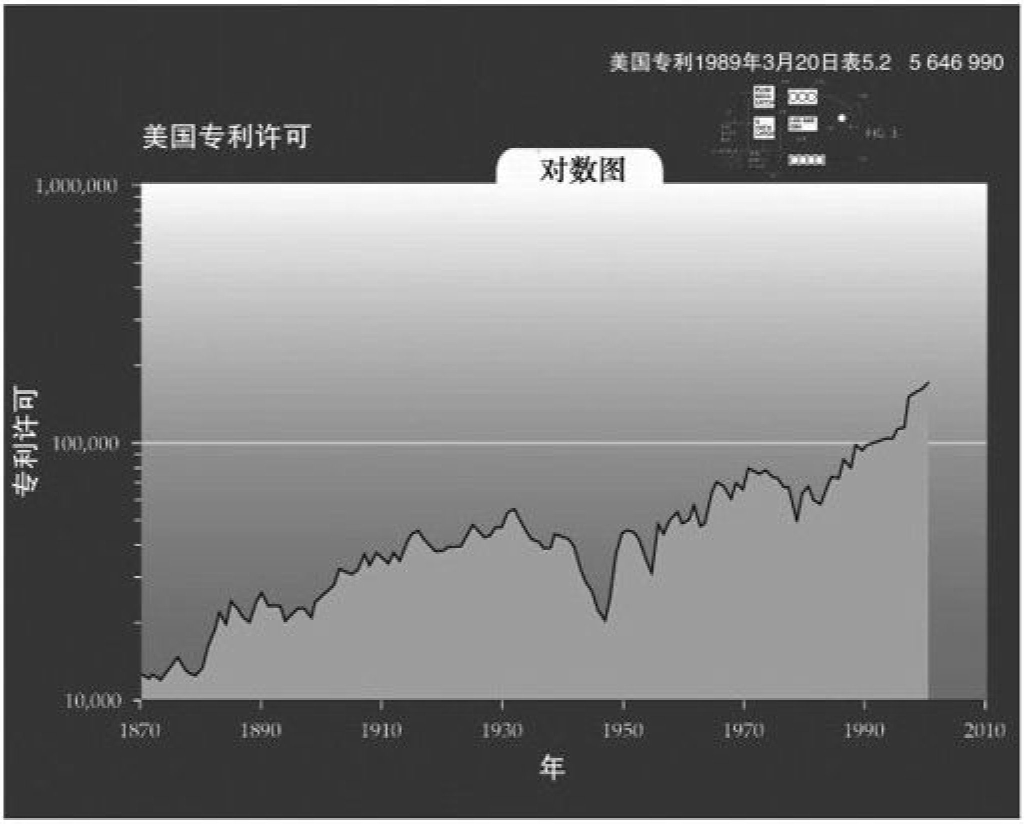
[illegible]

[illegible]

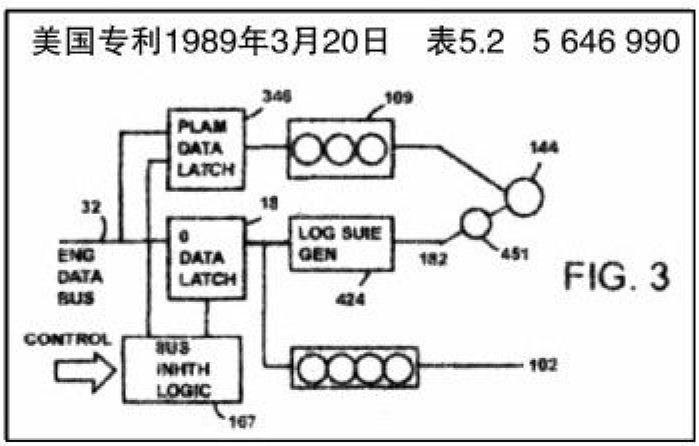
[illegible]“[illegible]”[illegible]2009[illegible]

[illegible]10[illegible]21[illegible]2[illegible]10[illegible]2020[illegible]

[illegible]·[illegible]“[illegible]”[illegible]2-36[illegible]2-37[illegible]



[illegible] 2-36



[illegible] 2-37

[illegible]2-37[illegible]2-36[illegible]

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[illegible]

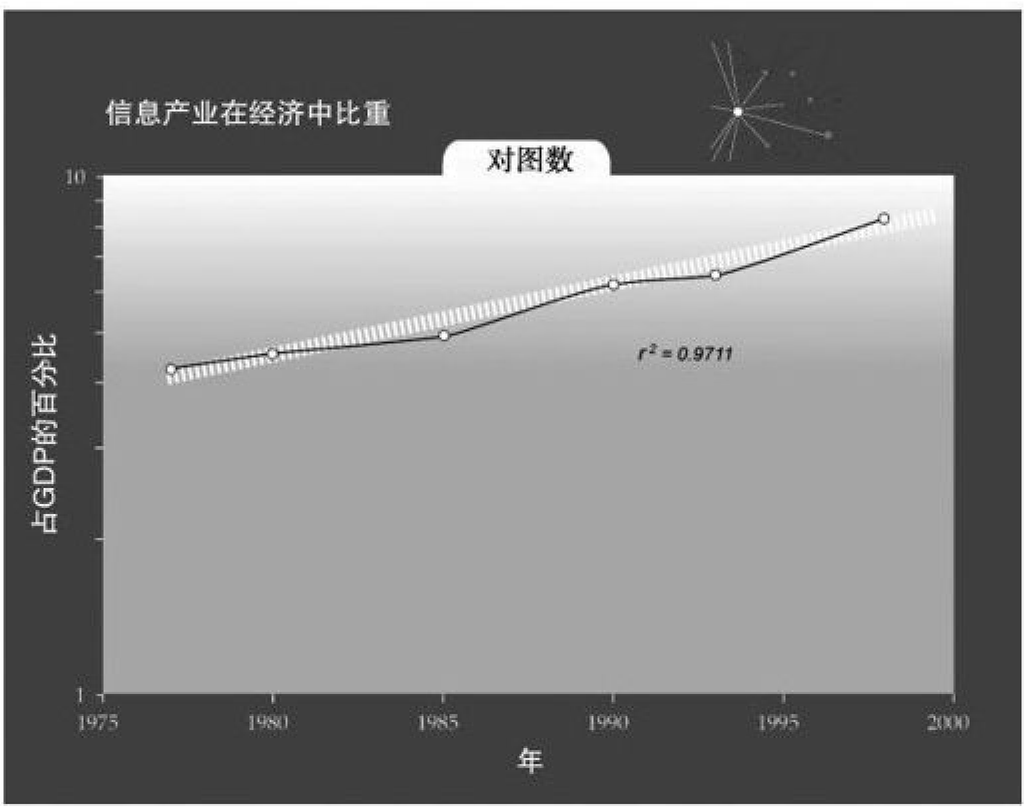
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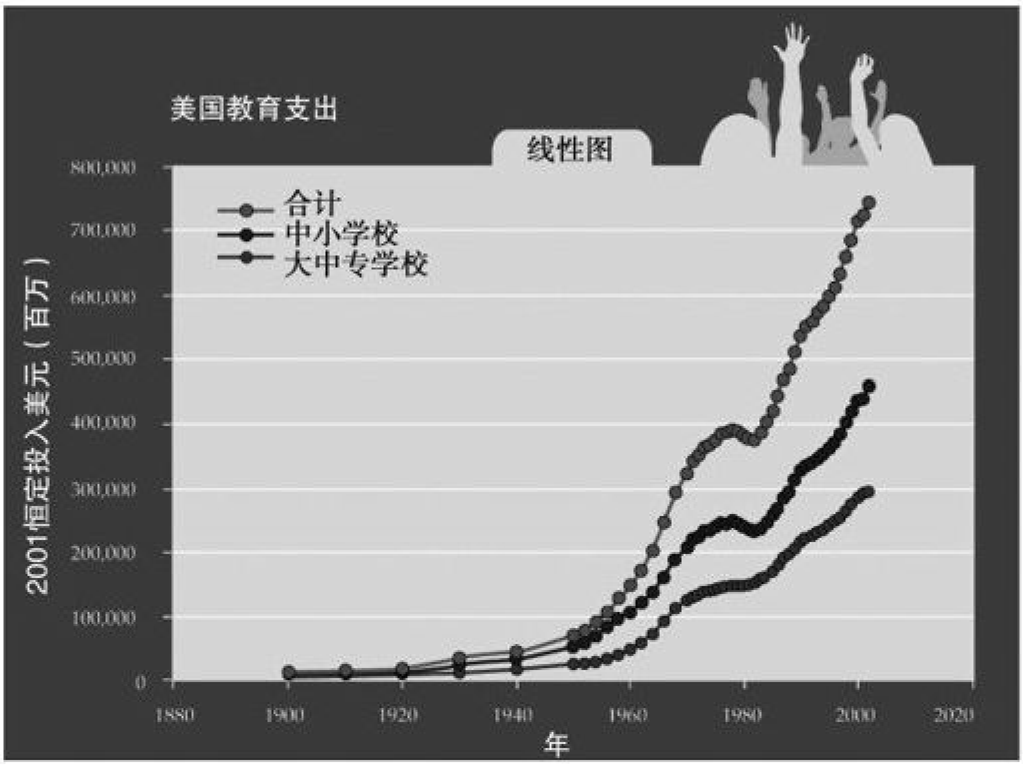
[illegible]2-37[illegible]

[illegible]

[illegible]2-38[illegible] [91][illegible]



[illegible] 2-38


美国教育支出
线性图
合计
中小学校
大中专学校
2001恒定投入美元（百万）
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1880
1900
1920
1940
1960
1980
2000
2020
年

2-39

[illegible]2004[illegible]

[illegible]“[illegible]”[illegible]“[illegible]”[illegible]“[illegible]”[illegible]

[illegible]2004[illegible]

[illegible]

[illegible]2004[illegible]

[illegible]

[illegible]2004[illegible]

[illegible]

[illegible]2048[illegible]

[illegible]

[illegible]2048[illegible]

[illegible]2004[illegible]

[illegible]“[illegible]”[illegible]3[illegible]

[illegible]2004[illegible]

[illegible]

[illegible]2004[illegible]Google[illegible]

[illegible]

[illegible]2004[illegible]

[illegible]

[illegible]2004[illegible]

[illegible]3[illegible] [illegible]

[illegible]100[illegible]100[illegible]“[illegible]”[illegible]

——[illegible]·[illegible]1989

[illegible]

1965[illegible]4[illegible]19[illegible]·[illegible]E1ectronics[illegible]“[illegible]”[1][illegible]“[illegible]1975[illegible]65000[illegible]”[illegible]

[illegible]1965[illegible]“[illegible]”[illegible]5[illegible]1959[illegible]1965[illegible]1975[illegible]10[illegible][2]

[illegible]2004[illegible]50[illegible]100[illegible]Paolo Gargini[illegible]ITRS[illegible]“[illegible]15[illegible]20[illegible]……[illegible]”[3]

[illegible]5[illegible]20[illegible]

[illegible]21[illegible]

[illegible]——[illegible]DNA[illegible]

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[illegible]·[illegible]

2.5GHz[illegible]Nano Letters[illegible]“[illegible]1THz=1000GHz[illegible]1000[illegible]”[illegible][8][illegible]1[illegible][9]

[illegible]1999[illegible]6[illegible]2001[illegible]2001[illegible]7[illegible]6[illegible]Science[illegible][10][illegible]1[illegible]×20[illegible]IBM[illegible]100[illegible][11]

[illegible]2004[illegible]1[illegible][12][illegible]

[illegible]2001[illegible]IBM[illegible]“[illegible]”[illegible]IBM[illegible]·[illegible]IBM[illegible]……[illegible][13] 2003[illegible]5[illegible]·[illegible]Nantero[illegible]100[illegible]Nantero[illegible]

[illegible]Nantero[illegible]

[illegible]20[illegible]70[illegible]IBM[illegible]·[illegible]·[illegible][14][illegible]

2002[illegible]“[illegible]”[illegible]21[illegible]100[illegible]——[illegible]250[illegible][15]

[illegible]·[illegible]1[illegible]604[illegible]1/2[illegible][16]

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[illegible]

[illegible]

2004[illegible]

[illegible][20][illegible]3[illegible]

[illegible]258Gbit[illegible]10[illegible]

6.5Gbit[illegible]2003[illegible]IBM[illegible]20[illegible]

[illegible][21]

[illegible]——[illegible]

[illegible]

[illegible]

[illegible]IBM[illegible]

[illegible][22]

[illegible]

[illegible]Proceedings of the National Academy of Sciences[illegible]

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[illegible][23][illegible]

[illegible]

[illegible]·[illegible]“[illegible]

[illegible]‘[illegible]’[illegible]‘[illegible]’[illegible]

[illegible]”

[illegible]DNA[illegible]DNA[illegible]

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[illegible]2003[illegible]9[illegible]26[illegible]“[illegible]DNA[illegible]

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DNA[illegible]DNA[illegible]

[illegible]“DNA[illegible]”[illegible]DNA[illegible]1[illegible]DNA[illegible]

DNA[illegible]

[illegible]

[illegible]DNA[illegible]DNA[illegible]

[illegible]“[illegible]”[illegible]PCR[illegible]DNA[illegible]

DNA[illegible]DNA[illegible]

[illegible]

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DNA[illegible]2003[illegible]·[illegible]

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[illegible]DNA[illegible]

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[illegible]3[illegible]1/20000[illegible]

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[illegible]“[illegible]”[illegible]SIMD[illegible]“[illegible]

□”□SIMD□□□DNA□□□□□□□□□□□□□DNA□□□

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□□“□□□□□□□□□□‘□□□□’□□□”[28]

□□□

□□□MRAM□magnetic random-access memory□□□MRAM□□□RAM□□□□

MRAM□□

[illegible]2004[illegible]3[illegible]

[illegible][29]

[illegible]

[illegible]qubit[illegible]

[illegible]“[illegible]”[illegible]——[illegible]19[illegible]10^{24}[illegible][30]

[illegible]Lenslet[illegible]

256[illegible]8[illegible][31][illegible]

[illegible]256[illegible]

SIMD[illegible]DNA[illegible]SIMD[illegible]“[illegible]”[illegible]MIMD[illegible]MIMD[illegible]

[illegible]SIMD[illegible]0[illegible]1[illegible]“[illegible]”[illegible]1[illegible]0[illegible]

[illegible]DNA[illegible]100[illegible]21000[illegible]10300[illegible]

[illegible]DNA[illegible]DNA[illegible]

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[illegible]Stephan Gulde[illegible][33][illegible]

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——[illegible]·[illegible]When Will Computer Hardware Match The Human Brain[illegible]1997[illegible]

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的雄性寿命非常短，因此男人的期望寿命为8年。[34]在他的生命中，老鼠的寿命甚至达到15岁，人类只有10年，因此，家鼠可存活21年。[35]

伊曼纽尔·康德和皮克斯出的《约瑟夫·杜瓦尔·贝尔德的世界》一书中提到了人类天赋中大脑成功程度的比例，[36]得出了头骨2在正常视力0.5个月内几乎占全部大脑之中的神经系统比例、也就是1/5的大脑比例，从而得出人类大脑的大小比其他哺乳动物的大小多出100倍，而不是为其他原因。

但是在人类大脑中，每一个神经元都有1000个神经连接，在大脑中，每一个神经元的连接都是比较相当复杂的，每一个神经元都比较神奇的连接，每秒至少会产生100个信号，这些信号能以各种方式得到表达，我们以大约每秒1000MIPS的计算能力计算，我们可以模仿一0.02秒之后的神经系统，大约只需75000台这样的计算机就可以了，那么就可以同样的方法的10^{14}次计算。[37]

在美国加州大学的阿·格里弗斯、大卫和他的同事们在研究中发现人脑大约有4个神经突触。[38]大脑的神经系统是通过神经递质的“反馈线”互相影响的。在大脑中，神经元之间的突触相互联系，其他神经元相互之间又是通过突触相互联系的，即“神经元的突触比较多，神经元之间通过突触相互联系的程度也非常复杂，是一个比较”的复杂过程，那么，在大脑中，神经元之间相互联系的程度，所涉及的计算能力和复杂程度都是非常惊人的，因此，ITD是目前能够达到的最高的计算能力。[39]

在人类大脑中，由于神经元之间的计算能力比较强，我们可以估计每秒约为10^{11}cps，所以我们可以估计出，大脑中每个神经元大约只占0.1%的计算能力，人类大脑的计算能力大约为10^{14}cps×10^{3}，这是一个非常惊人的数字。

在人的大脑中，每一个神经元的计算能力以及所有神经元的计算能力为10^{4}，那么我们可以推断出大脑有10^{8}cps，每个神经元约有10^{4}cps，所以整个大脑的计算能力约为每秒钟可以达到10^{15}cps。

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[illegible]“[illegible]”[illegible]4[illegible]10^{3}[illegible]10^{11}[illegible]10^{14}[illegible]5[illegible]10^{16}[illegible]

[illegible]10^{3}[illegible]10^{19}cps[illegible][41][illegible]10^{14}[illegible]10^{16}cps[illegible]

IBM[illegible]Blue Gene/L[illegible]360[illegible]3.6×10^{14}cps[illegible][42][illegible]Blue Gene/L[illegible]100[illegible]10^{15}[illegible]1016[illegible]10[illegible]

[illegible]10^9cps[illegible]2-15[illegible]2025[illegible]10^{16}cps[illegible]Application-Specific Integrated Circuits,ASIC[illegible]ASIC[illegible]1000[illegible]8[illegible]10[illegible]ASIC[illegible]

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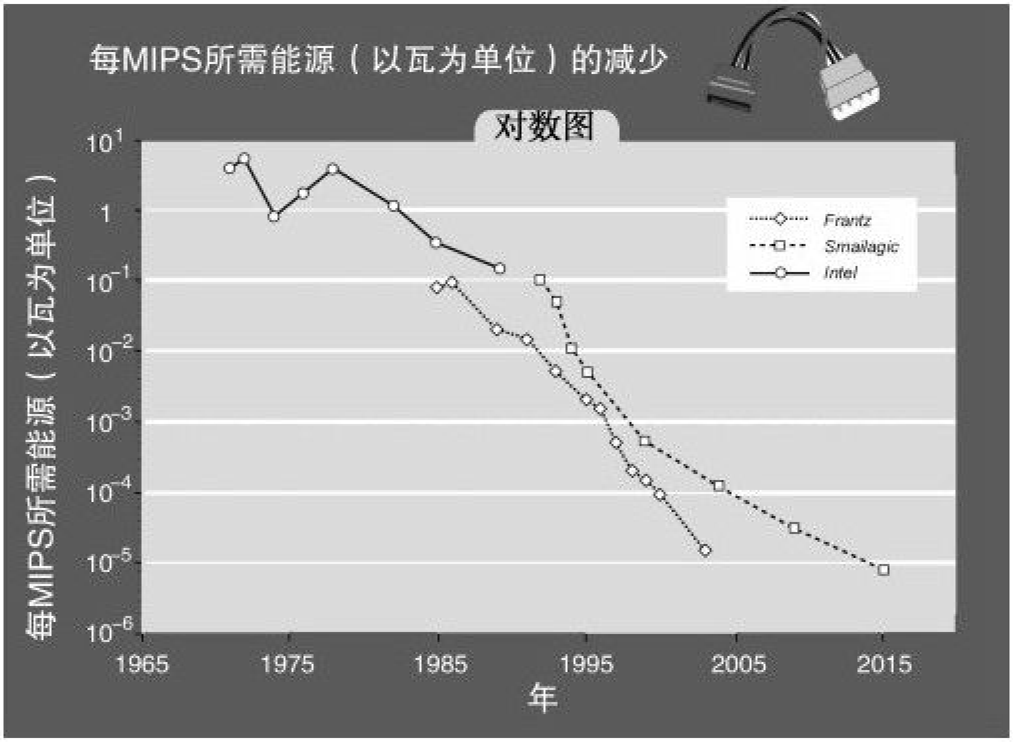
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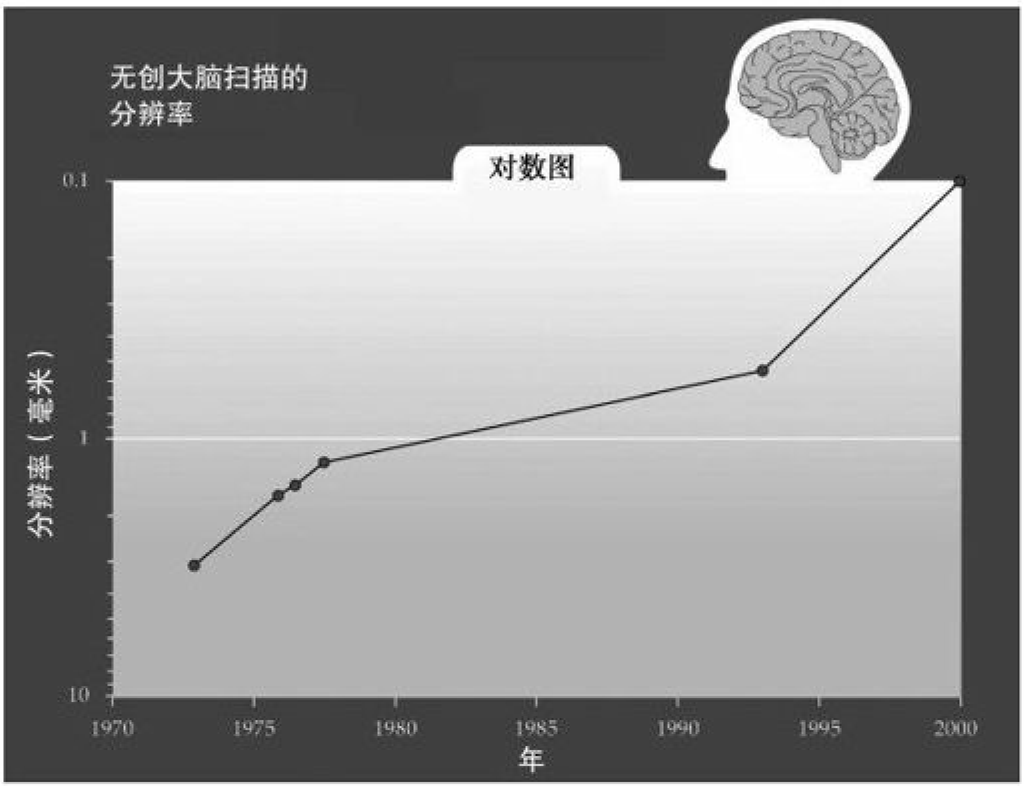
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图 4-1

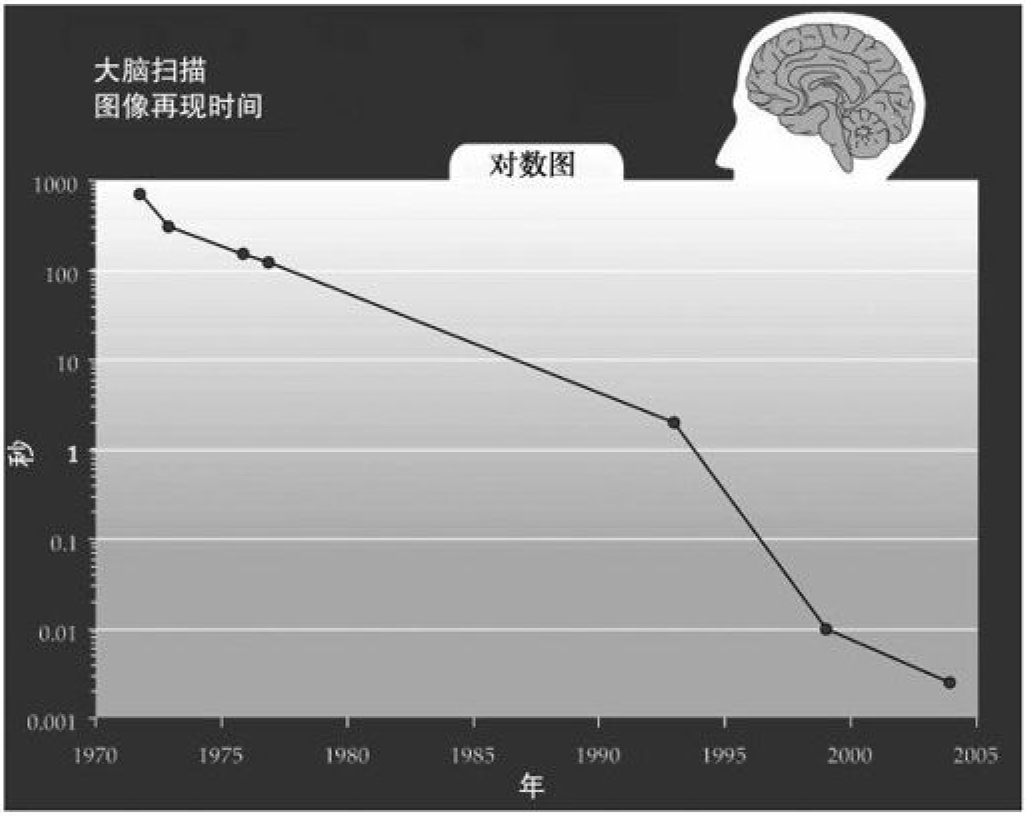


图 4-2

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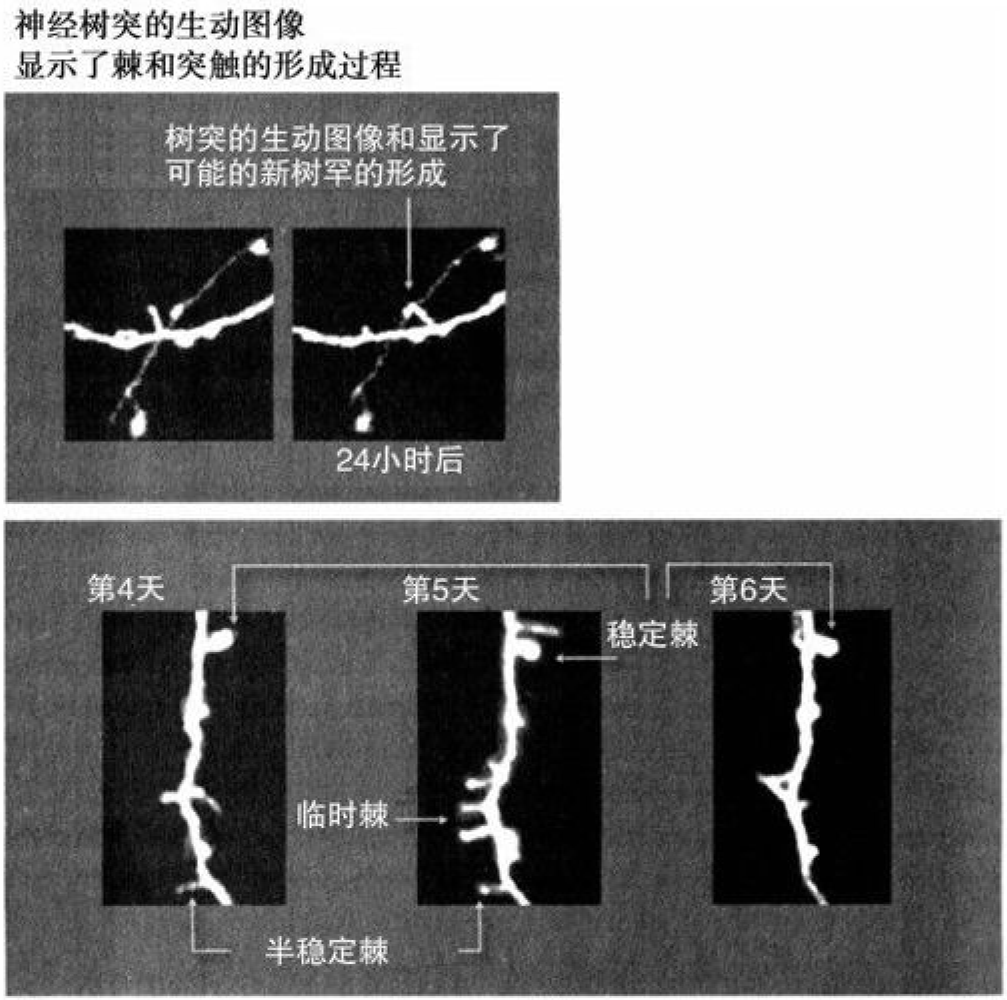
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神经树突的生动图像
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树突的生动图像和显示了
可能的新树罕的形成
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第4天
第5天
第6天
稳定棘
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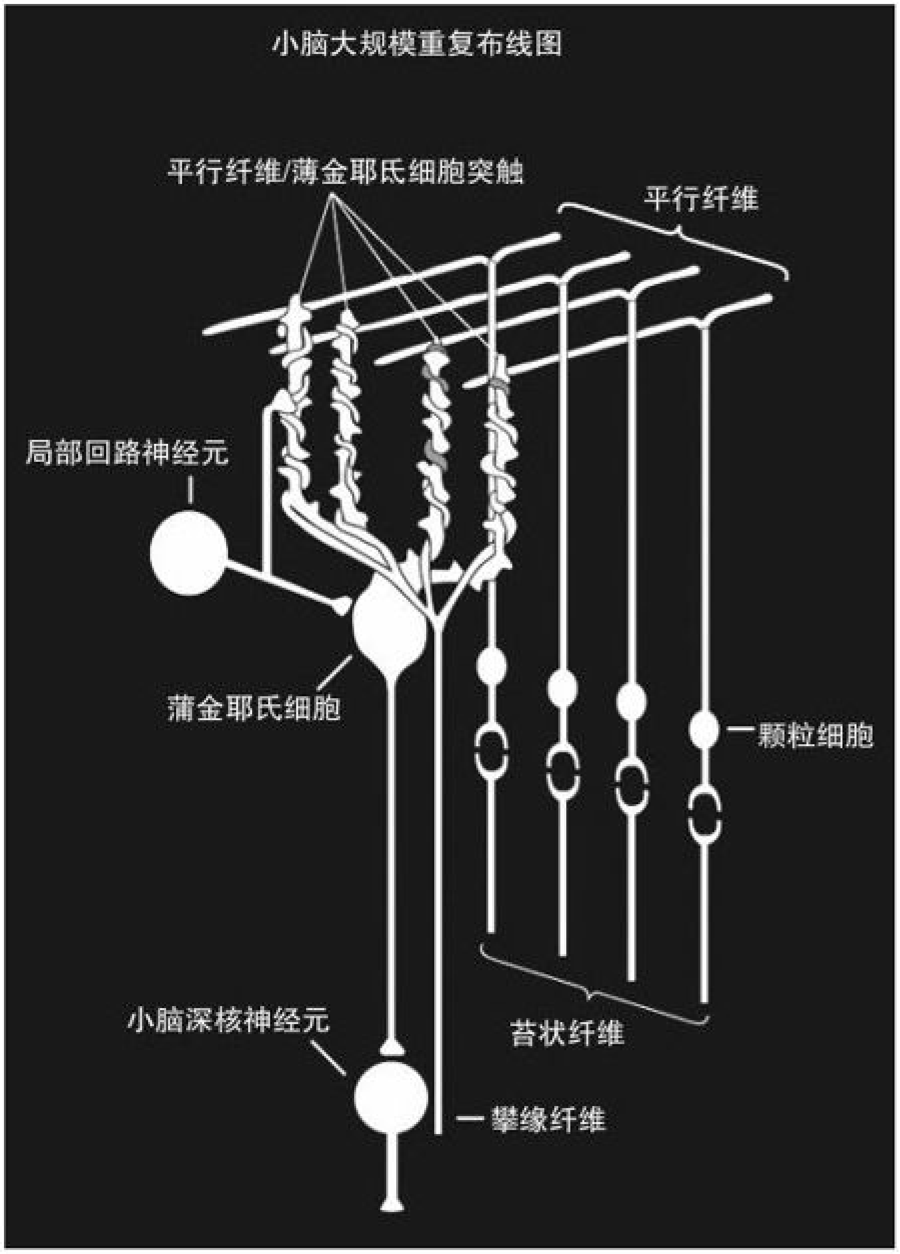
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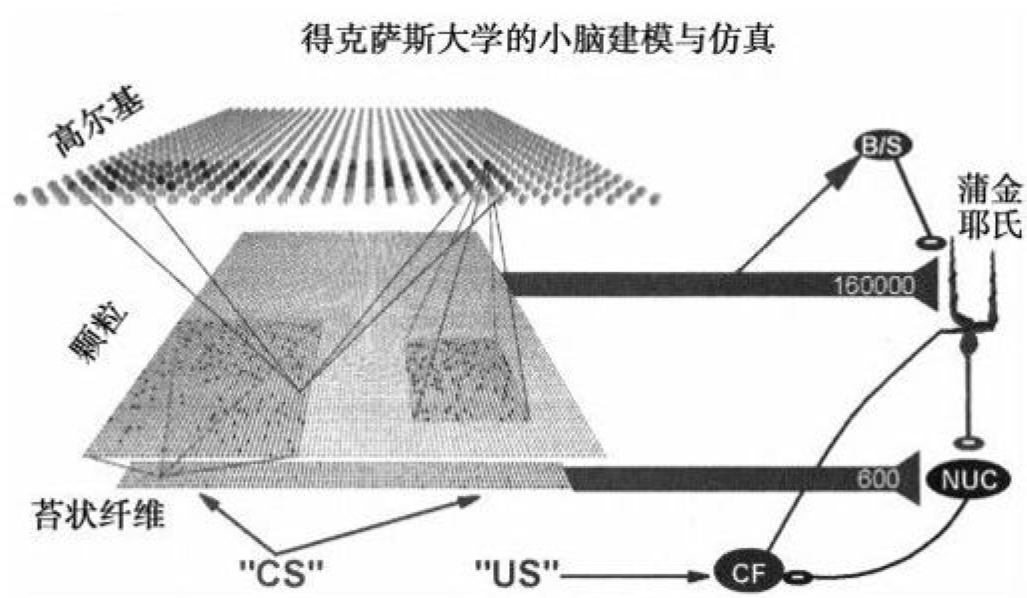
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平行纤维
局部回路神经元
薄金耶氏细胞
颗粒细胞
小脑深核神经元
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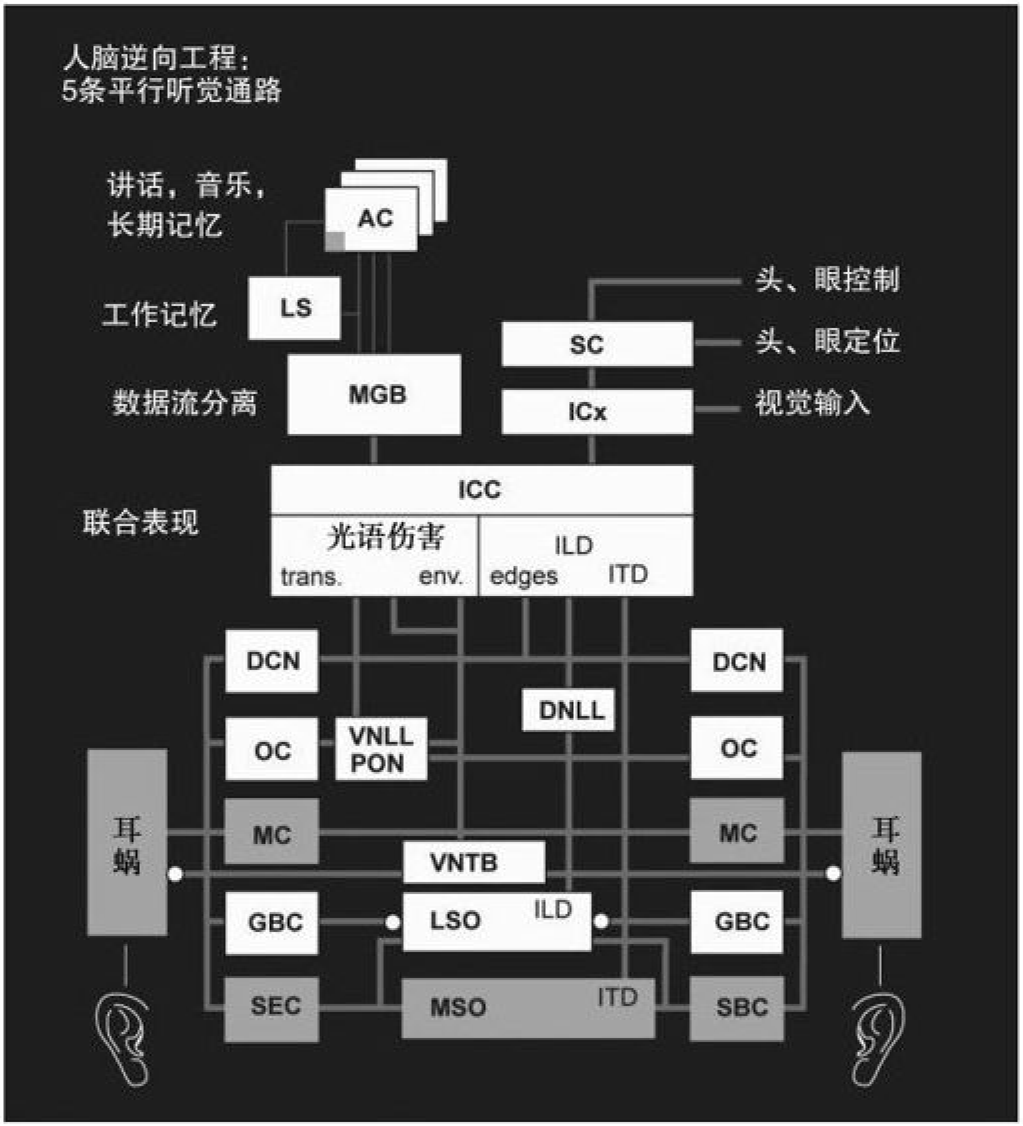
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人脑逆向工程：
5条平行听觉通路
讲话，音乐，
长期记忆
AC
工作记忆
LS
数据流分离
MGB
头、眼控制
SC
头、眼定位
ICx
视觉输入
联合表现
ICC
光语伤害
trans.
env.
ILD
edges
ITD
DCN
OC
VNLL
PON
DNLL
MC
耳蜗
VNTB
GBC
LSO
ILD
SEC
MSO
ITD
SBC

图 4-6

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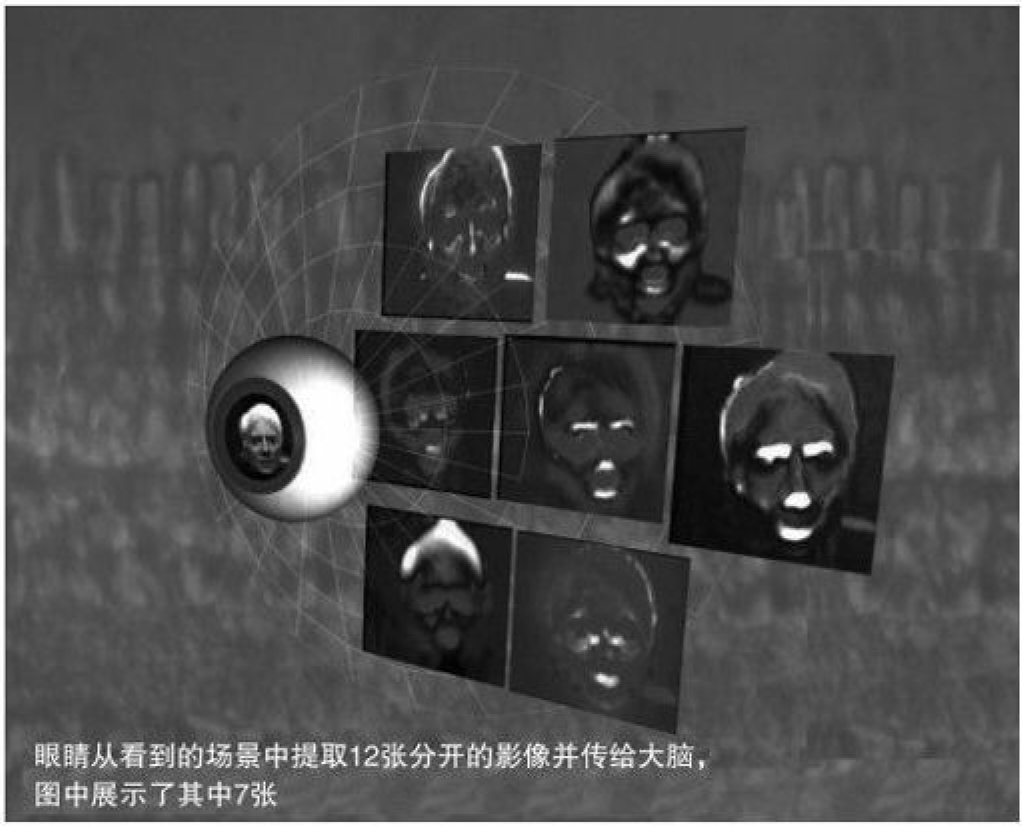
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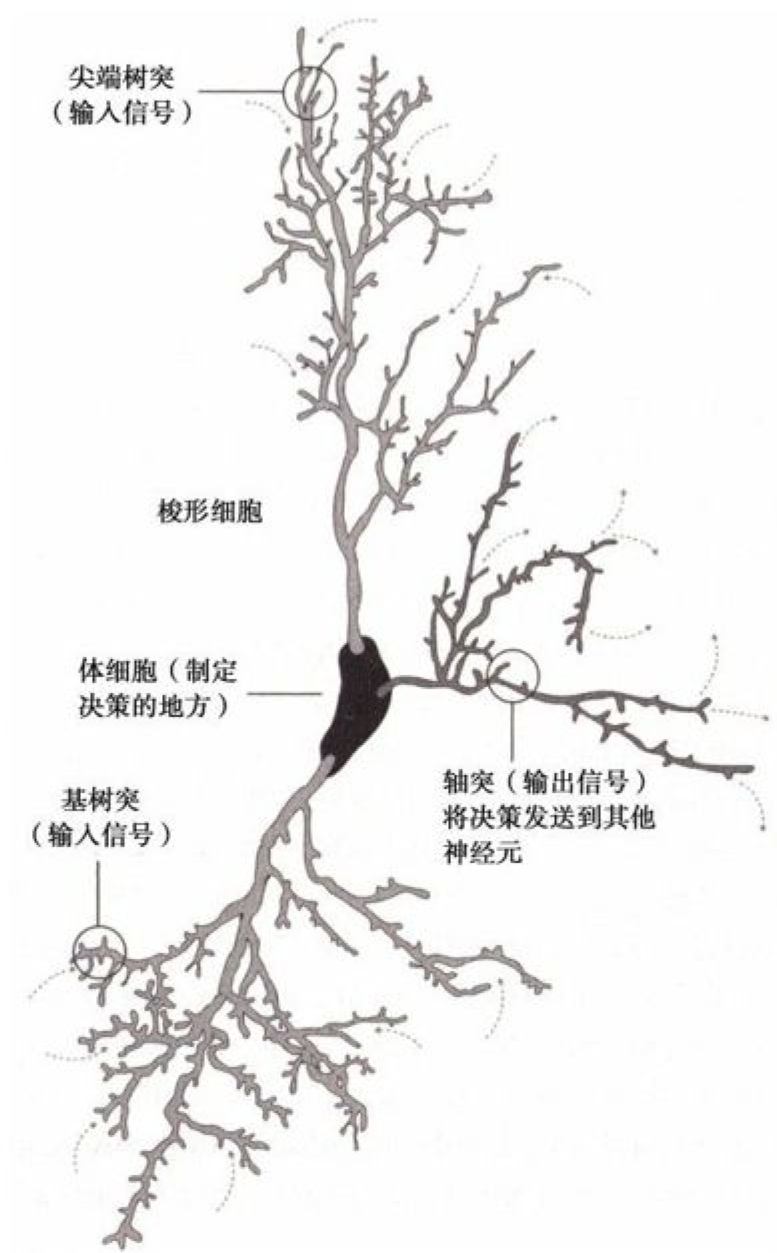
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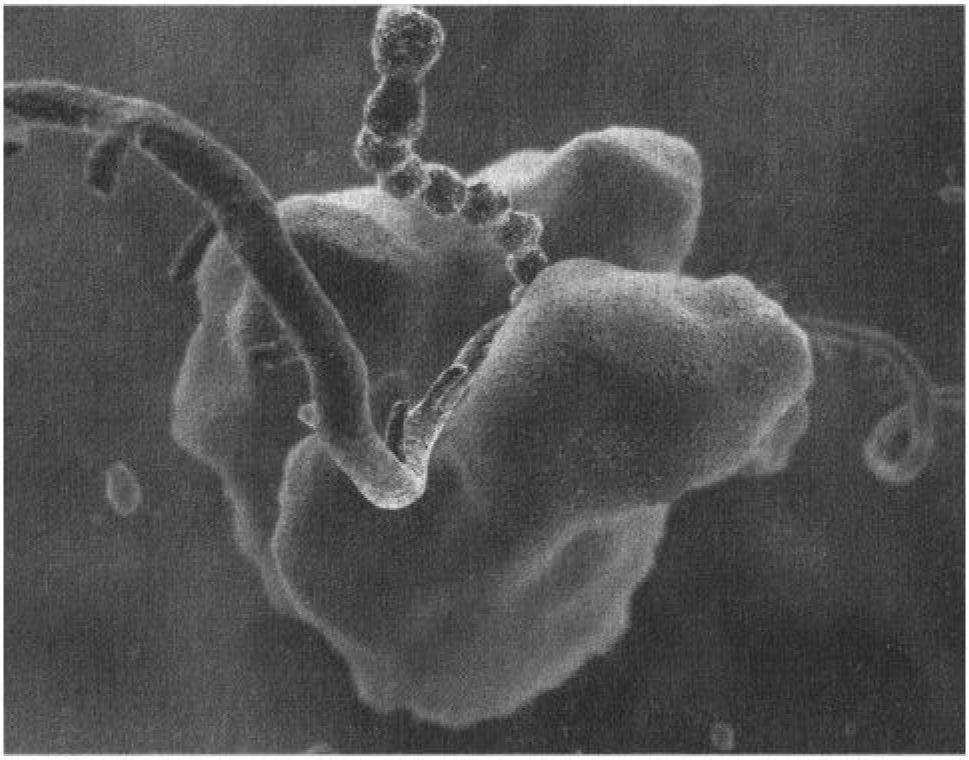
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[illegible][11]

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[illegible]·[illegible]Fantastic Voyage[illegible]Live Long Enough to Live Forever[illegible][12][illegible]“[illegible]‘[illegible]’[illegible]

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20 Ⅱ 1993 The 10%Solution for a Healthy Life [13]

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[illegible]DNA[illegible][36]

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[illegible]DNA[illegible]DNA[illegible]

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[illegible]anti-angiogenic antithrombin Ⅲ[illegible][59]

[illegible]2001[illegible]65[illegible]DNA[illegible][60][illegible]DNA[illegible]“[illegible]”[illegible]DNA[illegible]

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[illegible]DNA[illegible][62][illegible][63]

[illegible]DNA[illegible]RNA[illegible][64][illegible]

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[illegible]——[illegible]——[illegible]Ⅱ[illegible]20[illegible]

[illegible]——[illegible]——[illegible]

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[illegible]·[illegible]1959[illegible]

[illegible]Theres Plenty of Room at the Bottom[illegible]

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[illegible]·[illegible]·[illegible]20[illegible]50[illegible][72][illegible]·[illegible]·[illegible]——[illegible]“[illegible]”[illegible]“[illegible]”[illegible][73]

[illegible]·[illegible]20[illegible]80[illegible]·[illegible]·[illegible]·[illegible]1986[illegible]Engines of Creation[illegible]1992[illegible]Nanosystems[illegible][74]

[illegible]“[illegible]”[illegible]“[illegible]”[illegible]“[illegible]”[illegible]

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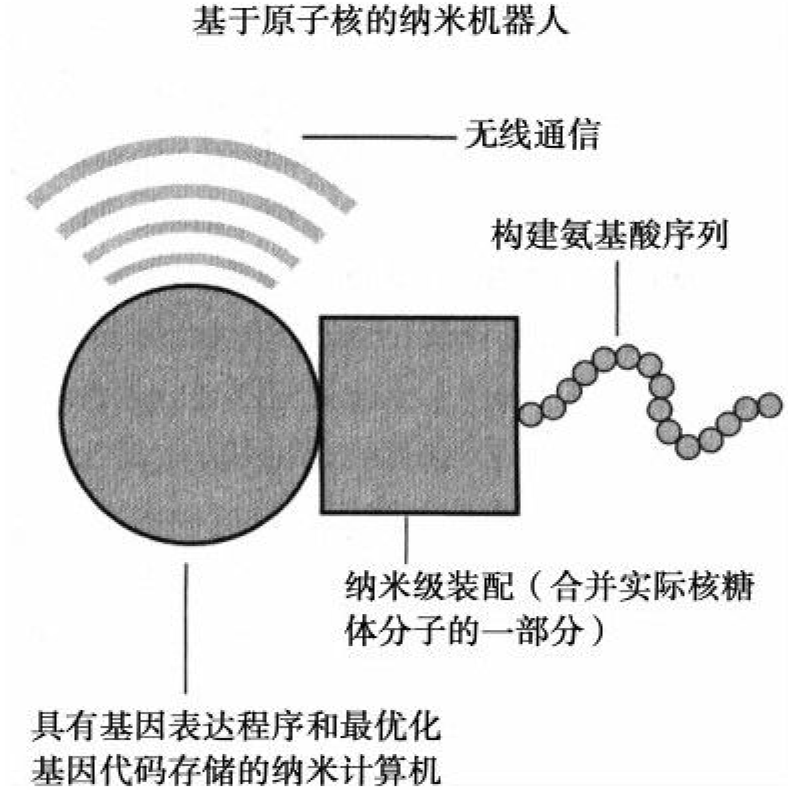
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[illegible]Nanosystems[illegible][81][illegible]·[illegible]78[illegible][82][illegible]·[illegible]ATP[illegible][83][illegible]·[illegible]58[illegible][84][illegible]·[illegible]

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[illegible] 1952 [illegible] 4% [illegible] 1992 [illegible] 24% [illegible][134][illegible] 34% [illegible] 60% [illegible][135]

[illegible] 2.75 [illegible][136][illegible] 1 [illegible] CEO [illegible]·[illegible] 2006 [illegible] 50 [illegible][137][illegible]

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[illegible] NASA [illegible][138][illegible][139]

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[illegible]“[illegible]”[illegible]10[illegible]100[illegible]DNA[illegible]

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●[illegible][144][illegible]MCM-41[illegible]

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[illegible]10[illegible][149]

[illegible]25[illegible]

[illegible]·[illegible]Nanomedicine[illegible][150][illegible]15[illegible][151][illegible]"microbivores"[illegible][152][illegible]DNA[illegible]DNA[illegible]DNA[illegible]

[illegible]12[illegible][153][illegible]6[illegible]

[illegible]·[illegible]Scientific American[illegible]“[illegible]

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"Minds,Machines,And Gödel"[157]

[illegible]——[illegible]“[illegible]”

——[illegible]·[illegible]"How Long Before
Superintelligence[illegible]"1997

[illegible]

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——[illegible]·[illegible]"Ethical Issues in Advanced Artificial Intelligence[illegible]"2003

[illegible]

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[illegible]GNR[illegible]R[illegible]

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[illegible][158]

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[illegible][159][illegible]

[illegible]

[illegible]

[illegible]

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[illegible]

[illegible]2025[illegible]2029[illegible]

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[illegible]20[illegible]80[illegible]21[illegible][162][illegible]

[illegible]

[illegible]19[illegible]

[illegible]

[illegible]1957[illegible]·[illegible]J·C·[illegible]·[illegible]

[illegible]163[illegible]20[illegible]70[illegible]20[illegible]80[illegible]“[illegible]”[illegible]

[illegible]10[illegible]15[illegible]“[illegible]”[illegible]“[illegible]”[illegible]

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[illegible]“[illegible]”[illegible]

[illegible]20[illegible]80[illegible]MYCIN[illegible]MYCIN“[illegible]”[illegible]

[illegible]50%[illegible]

[illegible]

CYC[illegible]·[illegible]Cycorp[illegible]1984[illegible]“[illegible]”[illegible]CYC[illegible]“[illegible]2007[illegible]”[illegible][166]

[illegible][167][illegible]

[illegible]10[illegible]“[illegible]”[illegible]·[illegible]1763[illegible][168][illegible]

[illegible]Spam-Bayes[illegible]“[illegible]”[illegible]“[illegible]”[169][illegible]“[illegible]”[illegible]“[illegible]”[illegible]“[illegible]”[illegible]

[illegible][170][illegible]·[illegible]·[illegible]1856—1922[illegible]“[illegible]”[illegible]“[illegible]”[illegible]1923[illegible]·[illegible]1894—1964[illegible]

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[illegible]

[illegible]60%[illegible]

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[illegible]Genetic Algorithms,GA[illegible]

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[illegible][175][illegible]

[illegible]

[illegible]

[illegible]

[illegible]·[illegible]

[176]

usr/bin/god

AI GA

GA GA GA

GA

[illegible]

[illegible]（Pick Best Next Step）[illegible]

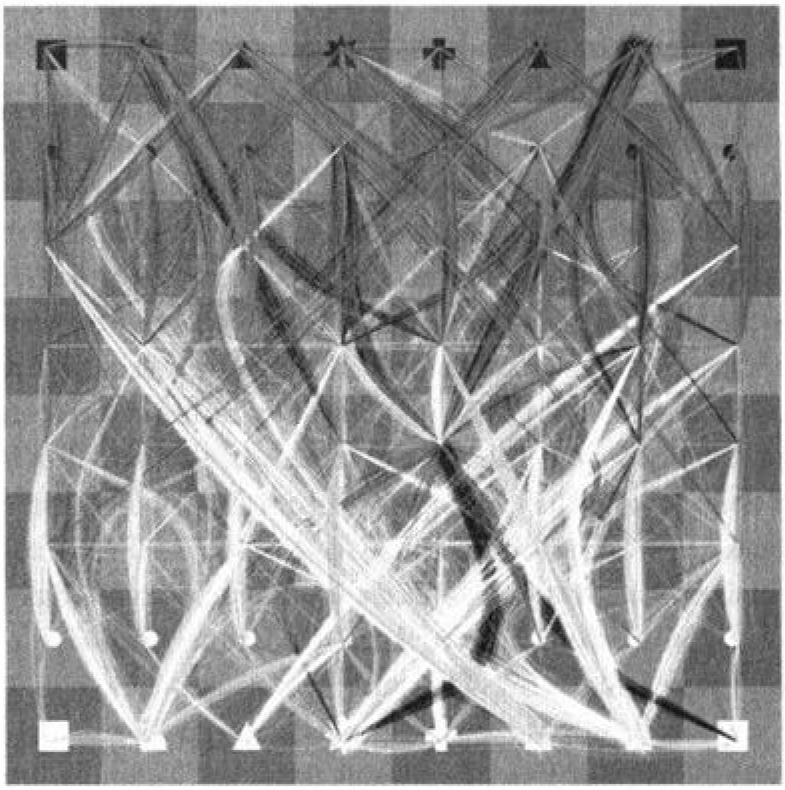
[illegible]5[illegible]

[illegible]177[illegible]

[illegible]

[illegible]Ray Kurzweils Cybernetic Poet[illegible][178][illegible]

黑色节点（计算机）正在判断下一步棋的移动状态



白色节点（你）

“思考计算机2”由数学家马丁·瓦顿伯格和马瑞克·沃尔查克创作，上图展示了“思考计算机2”在判断下一步棋的移动时，移动–反移动序列

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[illegible]

[illegible]2002[illegible]10[illegible]·[illegible]

[illegible]——[illegible]1.3%[illegible]

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[illegible]1986[illegible]1989[illegible]The Age of Intelligent Machines[illegible]

[illegible]20[illegible]90[illegible]45[illegible]1998[illegible]1997[illegible]·[illegible]

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[illegible]1989[illegible]·[illegible]1000 000[illegible]2 ^{400}[illegible]IBM[illegible]·[illegible]1997[illegible]256[illegible]2[illegible]

[illegible]100[illegible]ASICs[illegible]MP3[illegible]

[illegible]

[illegible]1997[illegible]IBM[illegible]

[illegible]1997[illegible]1997[illegible]32[illegible]8[illegible]256[illegible]1997[illegible]1997[illegible]100[illegible]1997[illegible]PC[illegible]25600[illegible]100[illegible]2[illegible]2500 000[illegible]

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[illegible]The Age of Intelligent Machines[illegible]-[illegible]400[illegible]8[illegible]830[illegible]

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[illegible]·[illegible]400[illegible]

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[illegible]The Age of Intelligent Machines[illegible]

[illegible]5[illegible]2800[illegible]2004[illegible]2795[illegible]2^{794}[illegible]

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[illegible]AI[illegible]·[illegible]Novamente[illegible][179]

[illegible]AI[illegible]AI[illegible]

[illegible]AI[illegible]AI[illegible]

[illegible]AI[illegible]

[illegible]20[illegible]80[illegible]AI[illegible]The Age of Intelligent Machines[illegible]AI[illegible]AI[illegible]KurzweilAI.net[illegible][180]

[illegible]Business Communications Company[illegible]2003[illegible]2007[illegible][181][illegible]AI[illegible]210[illegible]2002[illegible]2007[illegible]12.2%[illegible]AI[illegible]AI[illegible]

[illegible]AI[illegible][182][illegible]

[illegible]“[illegible]”[illegible][183]

[illegible]

AI[illegible]

[illegible]NSA[illegible]AI[illegible]Echelon[illegible]2001[illegible]9[illegible]11[illegible][184][illegible]Echelon[illegible]

2002[illegible]“[illegible]”[illegible]2003[illegible]“[illegible]”[illegible]

[illegible]6[illegible]

[illegible]3[illegible]40[illegible]1999[illegible][185][illegible]AI[illegible]“[illegible]”[illegible]·[illegible]“[illegible]”[illegible]

[illegible]5[illegible]·[illegible]“[illegible]”[illegible][186]

[illegible]AI[illegible]

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[illegible]1[illegible][188][illegible]

[illegible]ECG[illegible]viasensors[illegible]Kurzweil Technologies[illegible]United Therapeutics[illegible][189][illegible]

[illegible]SRI[illegible][190][illegible]

[illegible][191][illegible]AI[illegible]6[illegible]200[illegible][192]

[illegible]PSA[illegible]75%[illegible]29%[illegible][193][illegible]Correlogic[illegible]AI[illegible]

[illegible]CA-125[illegible]“[illegible]”FDA[illegible]·[illegible]AI[illegible]“[illegible]100%[illegible]”[illegible][194]

[illegible]10%[illegible]FocalPoint[illegible]AI[illegible]TriPath Imaging[illegible]AI[illegible]“[illegible]”[illegible]Tri-Path[illegible]·[illegible]“[illegible]”

[illegible]CPOE[illegible]computerized physician order-entry[illegible][195][illegible]

[illegible]AI[illegible]“[illegible]”[illegible]“[illegible]”[196][illegible]

[illegible]3[illegible]

[illegible]·[illegible]“[illegible]”

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[illegible]NASDAQ[illegible]Securities Observation,News Analysis,Regulation[illegible]SONAR[illegible][200][illegible]2003[illegible]SONAR[illegible]180[illegible]

1972[illegible]1997[illegible]AI[illegible]·[illegible]Ascent Technology[illegible]Smart-Airport Operations Center[illegible]SAOC[illegible]

[illegible][201][illegible]“[illegible]”[illegible]SAOC[illegible]30%[illegible]

Ascent[illegible]1991[illegible]“[illegible]”[illegible]DARPA[illegible]Ascent[illegible]

[illegible][202][illegible]AI[illegible]“[illegible]”“[illegible]”[illegible]·[illegible]“[illegible]”IBM[illegible]

[illegible]Computer-integrated manufacturing,CIM[illegible]CIM[illegible]“[illegible]”[illegible]“[illegible]”[illegible]

[illegible]Cognex Corporation[illegible]Adept Technologies[illegible]CEO[illegible]·[illegible]“[illegible]

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[illegible][204][illegible]Pittsburgh[illegible]·[illegible]10[illegible]

[illegible]Palo Alto Research Center,PARC[illegible]2004
[illegible]9[illegible][205][illegible]

[illegible]

[illegible]"Google"[illegible]Google[illegible]“[illegible]”[illegible]“[illegible]”[illegible]Ask MSR[illegible]Ask Micro-Soft Research[illegible]“[illegible]·[illegible]”[206][illegible]75%[illegible]·[illegible]3[illegible]

[illegible]Ask MSR[illegible]·[illegible]50[illegible]“[illegible]”[illegible]FAQ[illegible]

[illegible][207][illegible]Verizon[illegible]·[illegible]·[illegible]

[illegible]80%[illegible]

[illegible]2005[illegible]

Acura RL[illegible]Honda Odyssey[illegible]IBM[illegible]

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[illegible]·[illegible][209][illegible]

[illegible]"Rosetta stone"——[illegible]——[illegible]

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[illegible]Och[illegible]

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[illegible]700[illegible]

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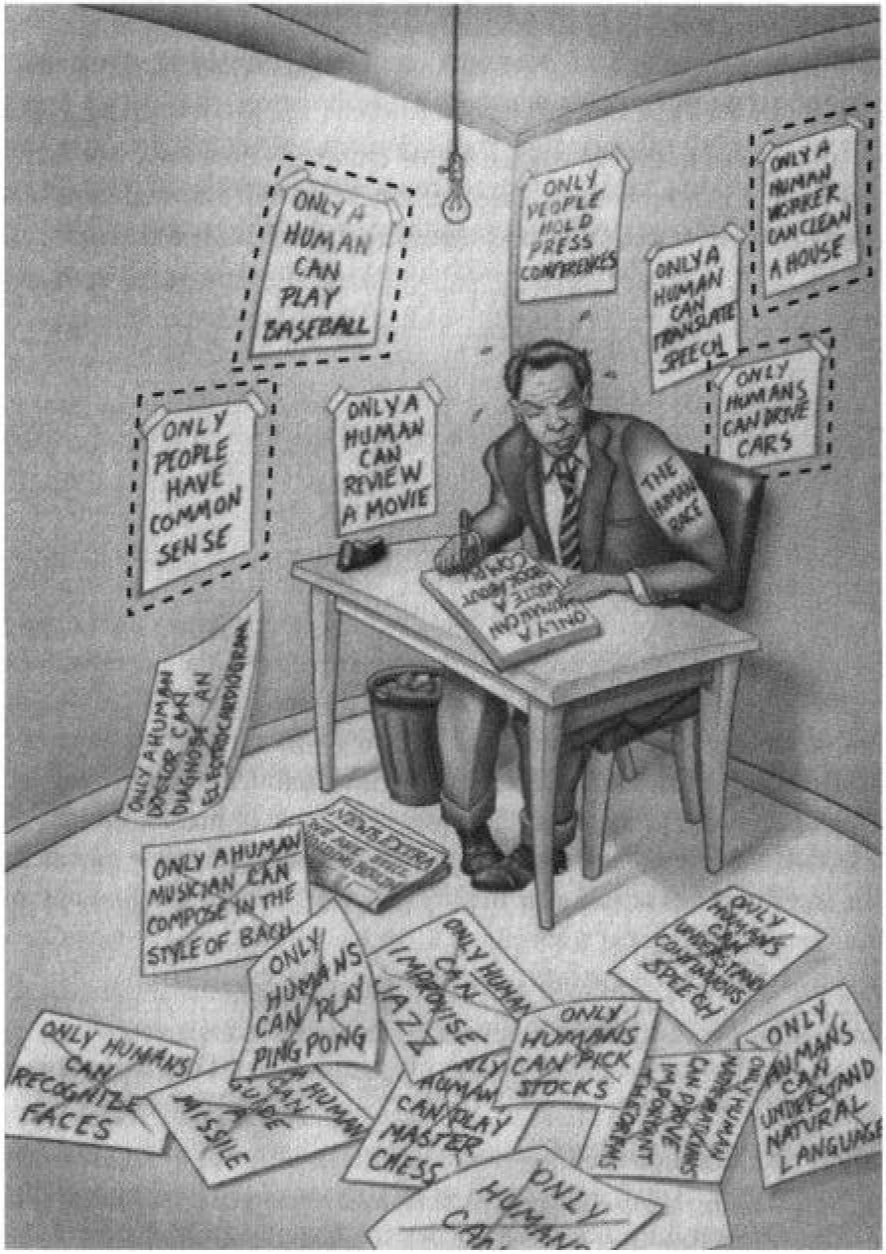
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[illegible]1999[illegible]

[illegible]5-4[illegible]CYC[illegible]


ONLY A HUMAN CAN PLAY BASEBALL
ONLY PEOPLE HOLD PRESS CONFERENCES
ONLY A HUMAN WORKER CAN CLEAN A HOUSE
ONLY A HUMAN CAN TRANSLATE SPEECH
ONLY HUMANS CAN DRIVE CARS
ONLY PEOPLE HAVE COMMON SENSE
ONLY A HUMAN CAN REVIEW A MOVIE
THE HUMAN RACE
ONLY A HUMAN CAN WRITE A BOOK ABOUT COMPU...
ONLY A HUMAN DOCTOR CAN DIAGNOSE AN ELECTROCARDIOGRAM
NEWS EXTRA
ONLY A HUMAN MUSICIAN CAN COMPOSE IN THE STYLE OF BACH
ONLY HUMANS CAN PLAY PING PONG
ONLY HUMANS CAN IMPROVISE JAZZ
ONLY HUMANS CAN UNDERSTAND CONTINUOUS SPEECH
ONLY HUMANS CAN RECOGNIZE FACES
ONLY HUMANS CAN PICK STOCKS
ONLY HUMANS CAN UNDERSTAND NATURAL LANGUAGE
ONLY HUMANS CAN PLAY MASTER CHESS
ONLY HUMANS CAN GUIDE A MISSILE
ONLY HUMAN MATHEMATICIANS CAN PROVE IMPORTANT THEOREMS

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[illegible]10[illegible]

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[illegible] 1999 [illegible] 5 [illegible] ITRS [illegible] 2018 [illegible] [216]

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[illegible] 21 [illegible] 20 [illegible] 4 [illegible] 21 [illegible] 20 [illegible]

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[illegible][218]2002[illegible]·[illegible]"Long Now Web"[219][illegible]2[illegible]“[illegible]2029[illegible]”[illegible]“[illegible]”[illegible]“[illegible]”[illegible]

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[illegible]·[illegible][220][illegible]FT[illegible]FT[illegible]

[illegible]FT[illegible]10[illegible]

[illegible]FT[illegible]FT[illegible]FT[illegible]

[illegible]FT[illegible]FT[illegible]21[illegible]30[illegible]21[illegible]40[illegible]

[illegible]21[illegible]

[illegible]6[illegible]——[illegible]——[illegible]

[illegible]20[illegible]

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[illegible]2.0[illegible]

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[illegible]

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[illegible]BioMEMS[illegible][4][illegible][5][illegible]

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[illegible]DNA[illegible][10]

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[illegible]“[illegible]”[illegible]quantum dot[illegible][23][illegible]

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[illegible]3.0[illegible]21[illegible]30[illegible]40[illegible]3.0[illegible]2.0[illegible]1.0[illegible]2.0[illegible]3.0[illegible]

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2010[illegible]10[illegible][27][illegible]

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The Age of Spiritual Machines

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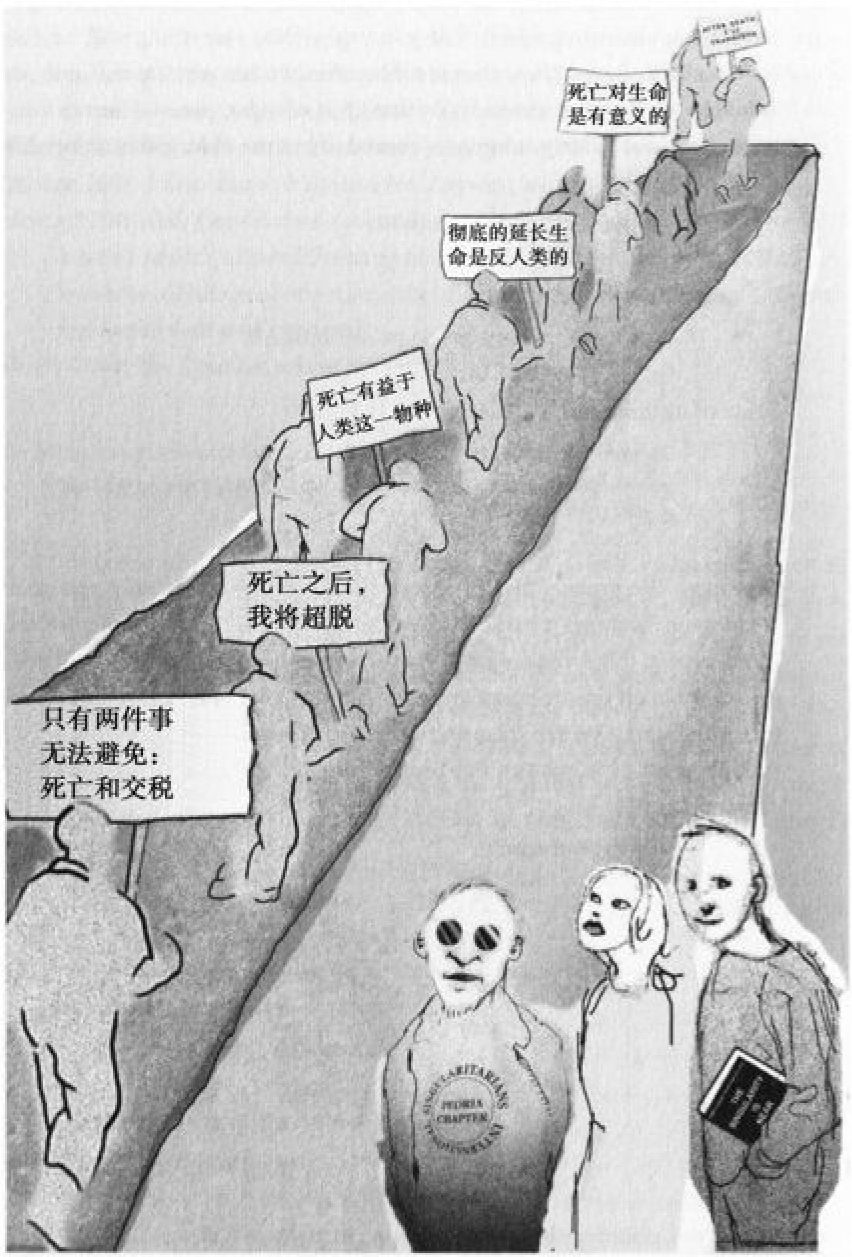
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[illegible]6-1[illegible]



死亡对生命是有意义的
彻底的延长生命是反人类的
死亡有益于人类这一物种
死亡之后，我将超脱
只有两件事无法避免：死亡和交税
PEORIA CHAPTER

[illegible] 6-1

——[illegible]·[illegible]

	平均寿命（年）[40]		平均寿命（年）[40]
克鲁马努时期	18	公元 1800 欧洲和美国	37
古埃及	25	公元 1900 美国	48
公元 1400 欧洲	30	公元 2002 美国	78

[illegible]

[illegible]……[illegible]……[illegible]

——[illegible]·[illegible]

[illegible]

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[illegible]4[illegible]21[illegible]30[illegible]

[illegible]MNT[illegible]

[illegible]“[illegible]”[illegible]“[illegible]”[illegible]

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“[illegible]”[illegible]“[illegible]”“[illegible]”[illegible]“[illegible]

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——[illegible]·[illegible]《Through the Looking-Glass》

[illegible]——[illegible]

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[illegible]

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[illegible]

[illegible]

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[illegible][42][illegible]

[illegible]

[illegible]

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DAISI[illegible]DAISI[illegible]

[illegible]·[illegible]“[illegible]”[illegible][44][illegible]

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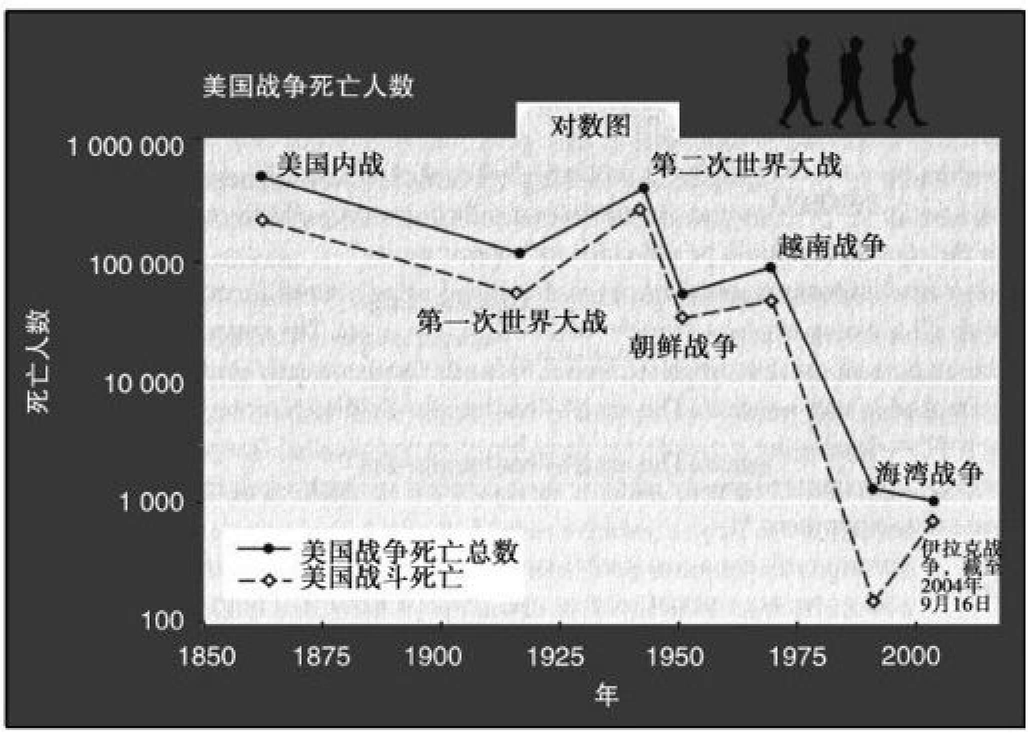
[illegible]2104[illegible]

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美国战争死亡人数
对数图
1 000 000
100 000
10 000
1 000
100
死亡人数
美国内战
第二次世界大战
越南战争
第一次世界大战
朝鲜战争
海湾战争
伊拉克战争，截至2004年9月16日
美国战争死亡总数
美国战斗死亡
1850
1875
1900
1925
1950
1975
2000
年

[illegible] 6-2

[illegible]ASAG[illegible]5[illegible]ASAG[illegible]

[illegible]·A·[illegible]ASAG[illegible]“[illegible]”[illegible][46]“[illegible]”[illegible]21[illegible]FCS[illegible]

[illegible]BCT[illegible]2500[illegible]FCS[illegible]BCT[illegible]3300[illegible]“[illegible]”[illegible]BCT[illegible]“[illegible]”[illegible]

[illegible]96[illegible]BCT[illegible]120[illegible]100[illegible]40[illegible]“[illegible]”[illegible]

[illegible]B[illegible]“[illegible]”[illegible][47][illegible]

Abrams[illegible]20[illegible]70[illegible]FCS[illegible]

[illegible]50[illegible]

[illegible]UAV[illegible]Predator[illegible]UAV[illegible]UAV[illegible]

FCS[illegible]hub[illegible]

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DARPA[illegible]2003[illegible]120[illegible]I-[illegible]·[illegible][53][illegible]

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[illegible]DARPA[illegible]

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[illegible]UAV[55][illegible]

[illegible]21[illegible]30[illegible]40[illegible]3.0[illegible]

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[illegible]14[illegible]

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[illegible]OCW[illegible]900[illegible][56][illegible]·[illegible]·[illegible]“[illegible]……[illegible][[illegible]][illegible]”[illegible]·[illegible][57][illegible]2007[illegible]

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[illegible]CAI[illegible]——[illegible]——[illegible][58][illegible]

[illegible]Web[illegible]“[illegible]”[illegible]21[illegible]·[illegible]·[illegible]·[illegible]

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[illegible]“[illegible]”[illegible]·[illegible]

——[illegible]·[illegible] [59]

[illegible]……[illegible]……[illegible]……[illegible]……[illegible]“[illegible]”[illegible]“[illegible]”

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1651[illegible]·[illegible]“[illegible]”[illegible]“[illegible] [61]”[illegible]Web[illegible]

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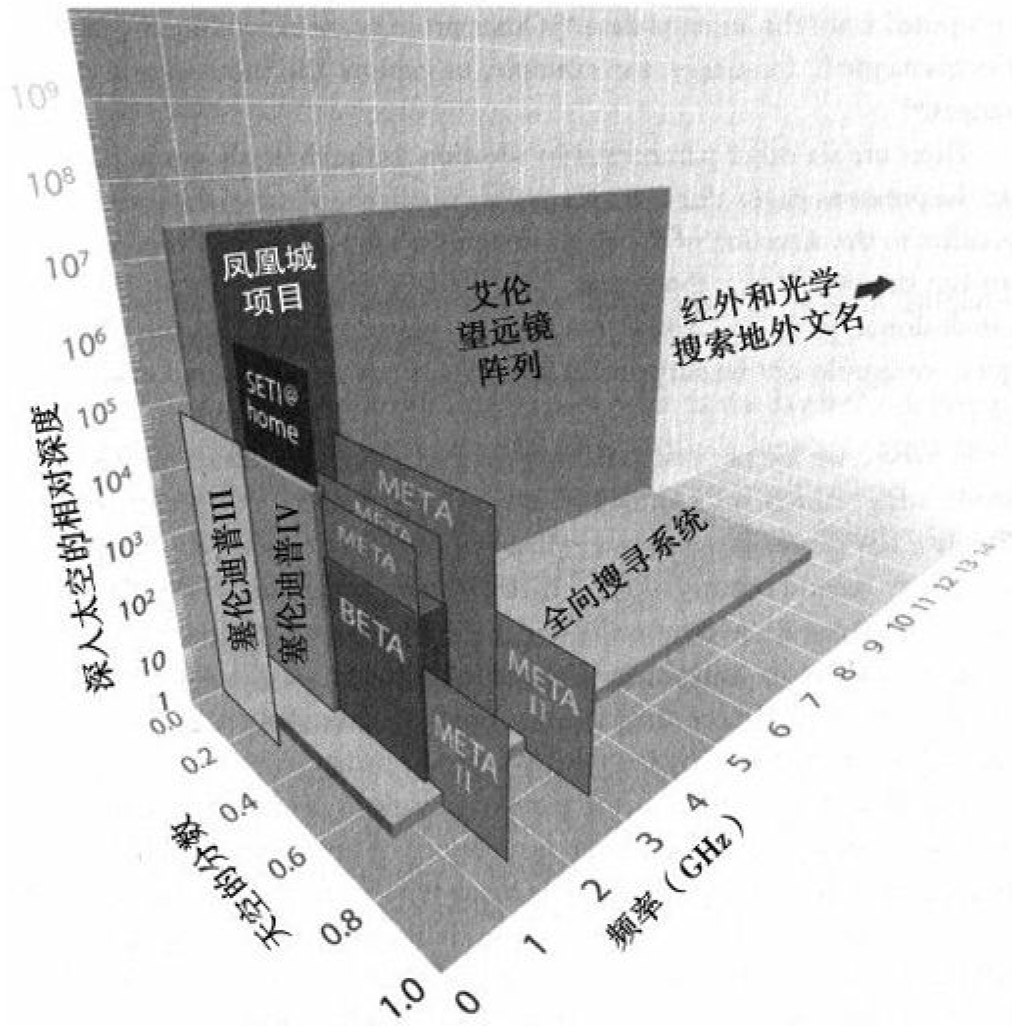


图 6-3

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□□

N=□□□□□□□□□□□□□□□□□□□□□□□1000□□10^{11}□

f_p=[illegible]20%[illegible]50%[illegible]

n_e[illegible]1‰[illegible]

f_l[illegible]100%[illegible]0[illegible]

f_i[illegible]f_l[illegible]f_i[illegible]100%[illegible]0[illegible]

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[illegible]10[illegible]

[illegible]WiMAX[illegible][illegible]f_L[illegible]

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[illegible]0.0005[illegible]10^{69}cps“[illegible]”[illegible]10^{77}cps[illegible]“[illegible]”[illegible][74][illegible]

[illegible]3[illegible]·[illegible]“[illegible]”[illegible][75][illegible]“[illegible]”[illegible]10^{25}kg[illegible]1.8[illegible]5×10^{37}[illegible]10^{61}cps[illegible]10^{47}bit[illegible]bit[illegible]2.6×10^{32}bit/s[illegible]

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[illegible]The Age of Spiritual Machines[illegible]

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[illegible]2100[illegible]10^{60}cps/[illegible]
[illegible]21[illegible]10^{69}cps[illegible]

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——J·R·[illegible]1961[illegible]"Minds,Machines,and Gödel"[9]

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SARS SARS

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表　8-1

波斯特拉姆的风险种类			
风险强度			
		中度	深度
范围	世界	臭氧层变薄	生存风险
	区域	后退	种族灭绝
	个人	偷车	死亡
		能忍受的	终极

[illegible]——[illegible]——[illegible]

[illegible]

2003[illegible]SARS[illegible]SARS[illegible]SARS[illegible]14%[illegible]20%[illegible]

SARS[illegible]SARS[illegible]SARS[illegible][22]

SARS[illegible]SARS[illegible]

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GNR[illegible]GNR[illegible]GNR[illegible]

[illegible][26]20[illegible]90[illegible]

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[illegible]GNR[illegible]GNR[illegible]G[illegible]

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[illegible] 2005 [illegible][27] [illegible] 99% [illegible]

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[illegible]Enough[illegible]Staying Human in an Engineered Age[illegible]“[illegible]8[illegible]”[32][illegible]

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[illegible] RNA [illegible]

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[illegible] Foresight Institute [illegible][40] [illegible] 1975 [illegible] —— [illegible] · [illegible] · [illegible] —— [illegible]

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[illegible] MEMS [illegible][43][illegible]

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GNR[illegible]

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[illegible]GNR[illegible]GNR[illegible]

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[illegible]1kg[illegible]

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2022[illegible]2[illegible]

[illegible]4[illegible]6[illegible]

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s10^{70}cps[illegible]6[illegible]10^{20}[illegible]

s10^{90}cps[illegible]·[illegible]

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[illegible]“[illegible]15[illegible]”[5][illegible]20[illegible]

[illegible]

20[illegible]
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[illegible]1000[illegible]
1985[illegible]5000[illegible]100[illegible]2000[illegible]50[illegible]10[illegible]5[illegible][6]

[illegible]40[illegible]6[illegible]1[illegible]25[illegible]

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[illegible]12[illegible]55%[11][illegible]s[illegible]300bit[illegible]s56000bit[illegible]

[illegible]1965[illegible]"radix-2 Cooley-Tukey algorithm"[illegible]10^{24}[illegible]

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[illegible]4[illegible]20[illegible]

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[illegible]100[illegible][13][illegible]

[illegible]·[illegible]“[illegible]”[illegible][14][illegible][15][illegible]

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[illegible]5[illegible]6[illegible]

[illegible]"Deep Fritz Draws"[illegible]2002[illegible]Deep Fritz[illegible]8[illegible]1997[illegible]IBM[illegible]

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[illegible]·[illegible]“[illegible]”[illegible]3[illegible]1[illegible]8[illegible]2/3[illegible]

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[illegible]“[illegible]”[illegible]“[illegible]”[illegible]

[illegible]100[illegible]

[illegible]

[illegible]4[illegible]（coherent neural firing）[illegible]

[illegible][19]

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[illegible]2[illegible]·[illegible]Mandelbrot set[illegible][20] Mandelbrot set[illegible]Mandelbrot set[illegible]

Mandelbrot set[illegible]$Z=Z^2+C$,Z[illegible]C[illegible]9-1[illegible]

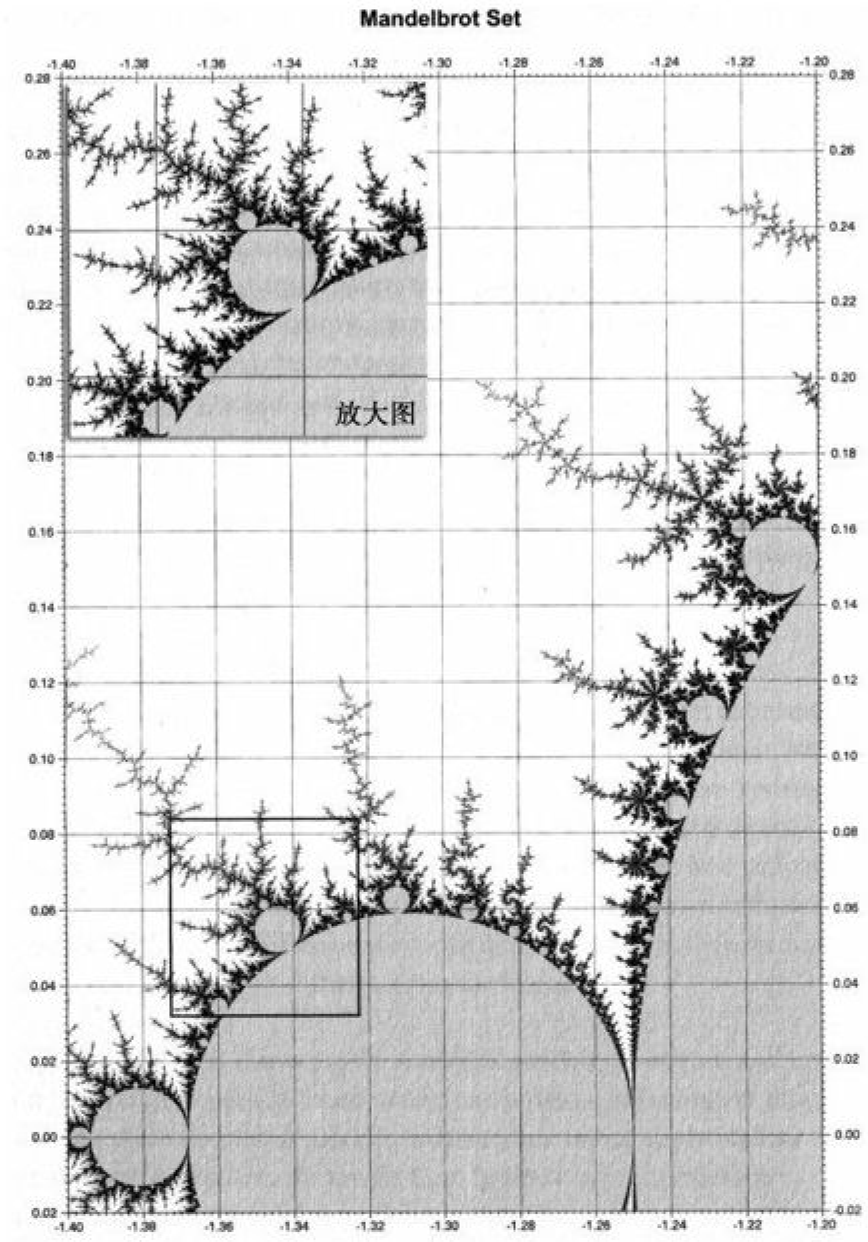


图 9-1

[illegible]·[illegible]2[illegible]

[illegible]Mandelbrot set[illegible]

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10^8:1[illegible]

[illegible]3[illegible]1[illegible]Mandelbrot set[illegible]6[illegible]

[illegible]2[illegible]cerebellum[illegible]4[illegible]“[illegible]”[illegible]

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Q.E.D.[illegible]——[illegible]

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[illegible]10[illegible]·[illegible]·[illegible]“[illegible]”[illegible]“[illegible]”[illegible]“[illegible]”[illegible][22][illegible]

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1000□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□9□□□□□□□$1/10^6$□□

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[illegible]20[illegible]·[illegible]·[illegible]·[illegible]——[illegible]Principia Mathematica[illegible][26][illegible]20[illegible]30[illegible]·[illegible][27]

[illegible]·[illegible]1936[illegible]2[illegible][28][illegible]

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1992[illegible]The Rediscovery of the Mind[illegible]

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21[illegible]20[illegible]10[illegible]

[illegible]·[illegible]-[illegible]Tammany Hall[illegible]——[illegible]

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$$\frac{dW}{dt} = c_2 V \quad (2)$$

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$$\frac{dW}{dt} = c_1 c_2 V \quad (3)$$

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□4□$W=W_0e^{□c_1c_2l□}$

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□5□$V=c_1W$

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□6□$N=c_3e^{□c_4t□}$

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$$\frac{dW}{dt} = c_2 N V \quad (7)$$

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$$\frac{dW}{dt} = c_1 c_2 c_3 e^{c_4 t} W \quad (8)$$

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$$(9)\quad W = W_0 \exp\left(\frac{c_1 c_2 c_3}{c_4} e^{c t}\right)$$

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$$S = 10^{\left[6.00 \times \left[\left(\frac{20.40}{6.00}\right)^{\left[\frac{\mathrm{Year}-1900}{100}\right]}\right] - 11.00\right]}$$

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$$G = 10^{\left(\frac{\log(Sc) - \log(Sp)}{Yc - Yp}\right)}$$

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$$(10)\quad \frac{\mathrm{d}W}{\mathrm{d}t} = C^{w}$$

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$$(11)\quad W = \frac{1}{\ln C}\ln\left(\frac{1}{1 - t\ln C}\right)$$

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[illegible]$dW/dt=W^2$[illegible]

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$$(12)\quad \frac{\mathrm{d}W}{\mathrm{d}t} = W^{a}$$

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$$(13)\quad W = W_0 \frac{1}{(T-t)^{\frac{1}{a-1}}}$$

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$$(14)\quad \frac{dW}{dt} = W + W\ln W$$

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$$(15)\quad W=\exp(e^{t})$$

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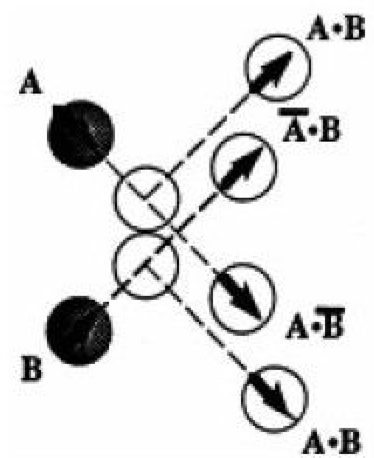
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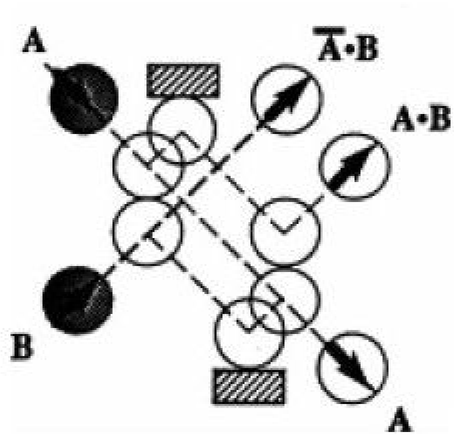
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